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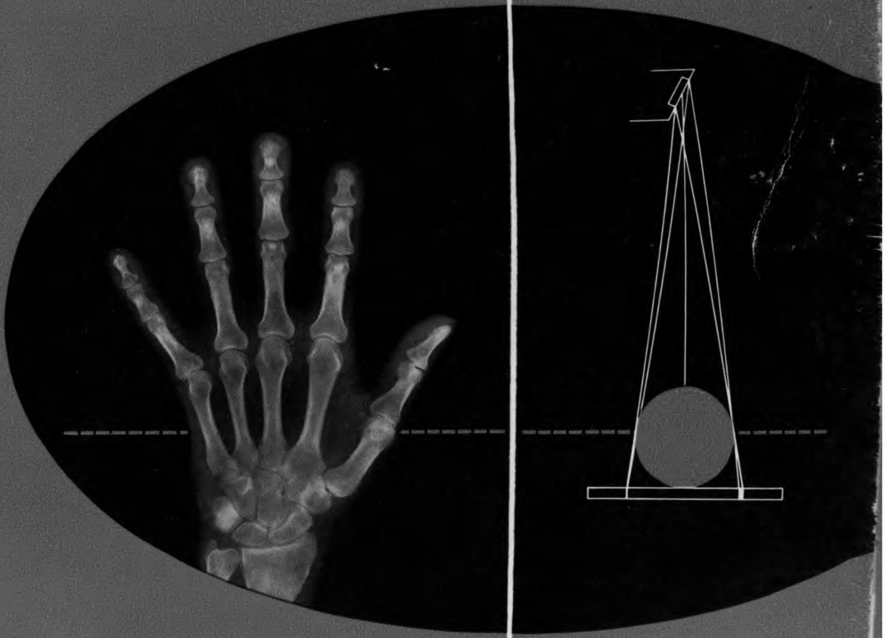

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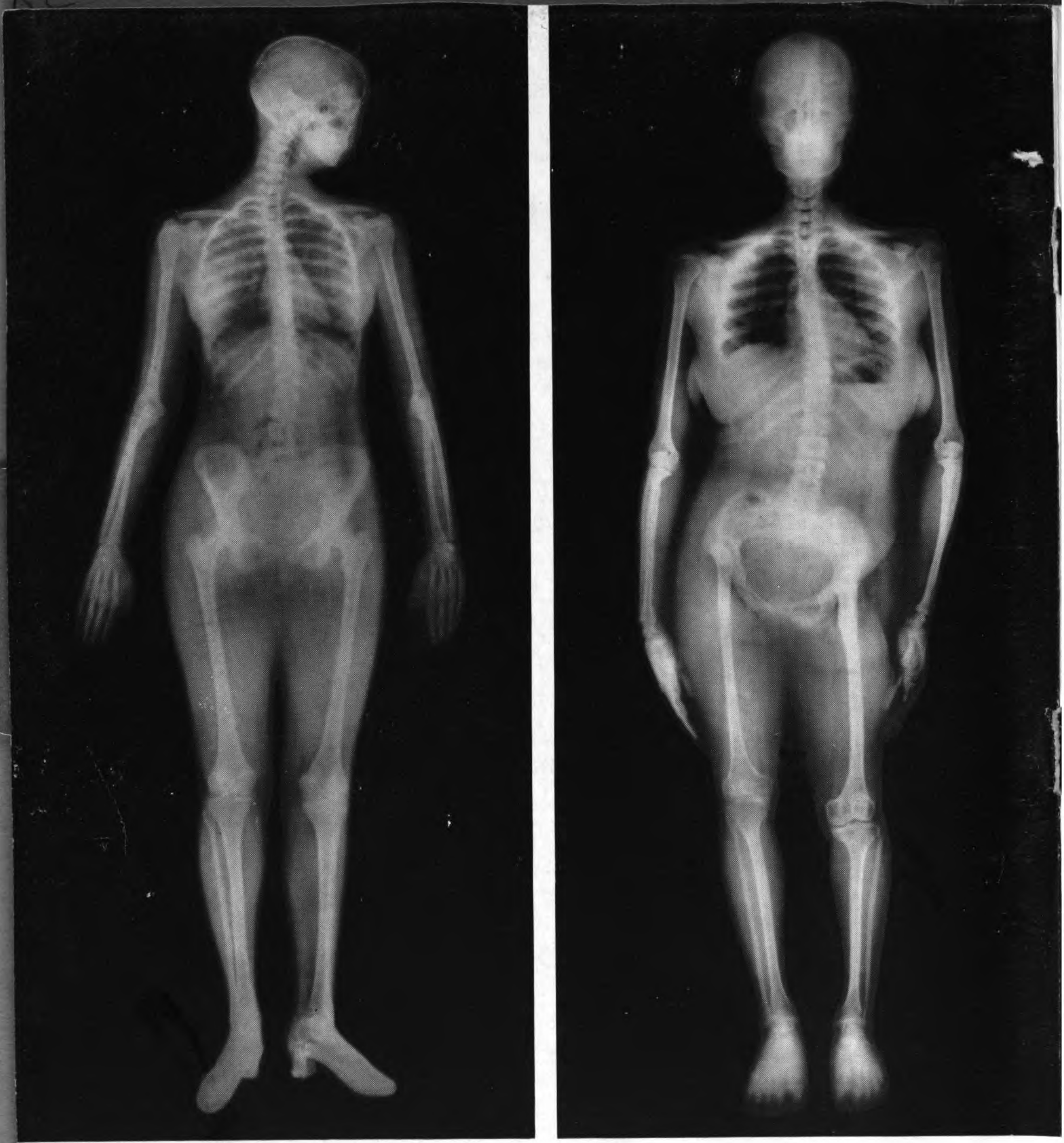

Radiographs of entire bodies of living people, each made with one exposure on Kodak x-ray film, 32x72 inches in size. **LEFT:** 18-year-old girl with normal bone structure. **RIGHT:** 30-year-old woman with hip deformities.

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The Fundamentals of Radiography

Seventh Edition • April, 1951

Medical Division
EASTMAN KODAK COMPANY
Rochester 4, N. Y.

RC

No. 17288

• The purpose of this publication is to provide a concise elementary text describing the principles involved in the formation and recording of the radiographic image. The text is presented in a manner which generally follows the steps necessary to the production of a radiograph of satisfactory quality.

No attempt is made to discuss anatomy or the intricacies of x-ray apparatus. The former is completely covered in anatomic textbooks. As for the latter, the manufacturers of x-ray apparatus publish excellent technical information which may be secured upon request. Numerous volumes on the latter subject may also be secured from medical or technical libraries.

The beginner in radiography can acquire a sound understanding for technical training by studying this publication. The more advanced worker will find the book a source of useful information in solving problems encountered in routine radiography. In the event questions arise that are not fully explained in this book, they may be presented by letter to the *Medical Division,* Eastman Kodak Company, Rochester 4, N. Y., and every effort will be made to supply appropriate answers.

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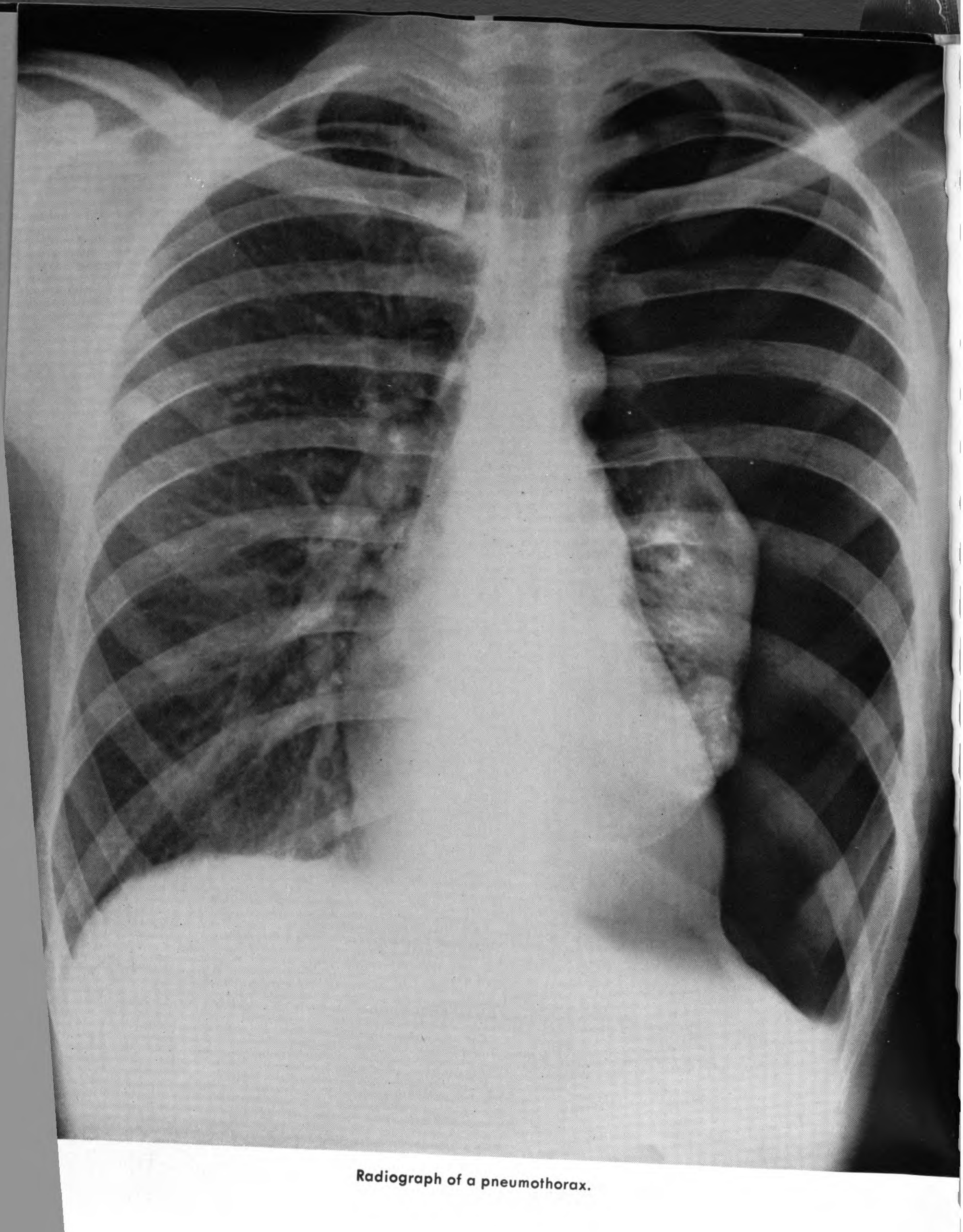

Radiograph of a pneumothorax.

History

• The discovery of x-rays was made possible by the cumulative efforts of many scientists over a period of three hundred years. It represented long study of the properties and production of electricity, such as high-tension currents and discharge phenomena of highly evacuated tubes.

On November 8, 1895, the x-rays were discovered by Wilhelm Conrad Röntgen, a Professor of Physics and Director of the Physical Institute of the University of Würzburg, Germany. The phenomenon was first detected by the fluorescence of a small barium platinocyanide screen which was excited by unknown rays from a shielded and energized Crookes tube. The best detailed description of this momentous discovery was given on November 5, 1897 by Sylvanus P. Thompson, a prominent English physicist and a founder of the British Roentgen Society. He wrote as follows:

Wilhelm Conrad Röntgen

> November the eighth, 1895, will ever be memorable in the history of Science. On that day a light which, so far as human observation goes, never was on land or sea, was first observed. The observer, Prof. Wilhelm Conrad Röntgen. The place, the Institute of Physics in the University of Würzburg in Bavaria. What he saw with his own eyes, a faint flickering greenish illumination upon a bit of cardboard, painted over with a fluorescent chemical preparation. Upon the faintly luminous surface a line of dark shadow. All this in a carefully darkened room, from which every known kind of ray had been scrupulously excluded. In that room a Crookes tube, stimulated internally by sparks

from an induction coil, but carefully covered by a shield of black cardboard, impervious to every known kind of light, even the most intense. Yet in the darkness, expressly arranged so as to allow the eye to watch for luminous phenomena, nothing visible until the hitherto unrecognized rays, emanating from the Crookes tube and penetrating the cardboard shield, fell upon the luminescent screen, thus revealing their existence and making darkness visible.

From seeing the illumination by the invisible rays of a fluorescent screen, and the line of shadow across it, the work of tracing back that shadow to the object which caused it, and of verifying the source of the rays to be the Crookes tube, was to the practised investigator but the work of a few minutes. The invisible rays — for they were invisible save when they fell upon the chemically painted screen — were found to have a penetrative power hitherto unimagined. They penetrated cardboard, wood, and cloth with ease. They would even go through a thick plank, or a book of 2000 pages, lighting up the screen placed on the other side. But metals such as copper, iron, lead, silver, and gold were less penetrable, the densest of them being practically opaque. Strangest of all, while flesh was very transparent, bones were fairly opaque. And so the discoverer, interposing his hand between the source of the rays and his bit of luminescent cardboard, *saw* the bones of his living hand projected in silhouette upon the screen. The great discovery was made.*

Röntgen's discovery has greatly extended our scientific vision from our knowledge of the visual spectrum to a broad range of wave lengths in the invisible portion of the spectrum which are now employed for our everyday comfort, safety, and education. The x-rays have made possible further differentiation of chemi**cal elements and have become a tool for chemical analysis and determination and identification of crystal** structure. In industry, they serve as a nondestructive means of examining numerous fabricated items. The significance of the application of x-rays in medical, dental, and biologic fields has been enormous, and constant progress is being made toward even greater usefulness.

Photography played a part in Röntgen's discovery, for on the photographic plate much of the phenomena Röntgen described were recorded. As the science of radiology developed, plates or films were improved to record an amazing gamut of x-ray applications in science, medicine, and industry.

In this connection mention should be made of three contributions to this progress by Eastman Kodak Company. First was the production of a single-coated nitrate base x-ray film just prior to World War I (1914). This was followed, in 1918, by double-emulsion *(Dupli-Tized)* x-ray film which made shorter exposures possible. It overcame the deficiencies of glass plates, which were heavy and easily broken. In 1924, safety *Dupli-Tized* x-ray film was introduced; the base consisted essentially of cellulose acetate.

Experimentation has continued with the years; progress is steadily being made in film speed and uniformity. The enormous demands for x-ray film by the Armed Forces in World War II have proved that the fundamentally sound production methods underlying all Kodak x-ray materials have made feasible swift radiography of injury or disease.

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*From *The Science of Radiology* edited by Otto Glasser; Chapter 1, "The Discovery of the Roentgen Rays." Publisher: Charles C Thomas, Springfield, Ill.

Production of X-rays

• X-rays are an invisible form of radiant energy of very short wave lengths. They are quite similar to light in that they travel at the same speed and obey many of the same laws. A distinguishing feature of x-rays is their extremely short wave lengths — only about 1/10,000 the wave length of *visible* light. It is this characteristic that is responsible for the x-rays' ability to penetrate materials that ordinarily would absorb or reflect light. The useful range of wave lengths for medical radiography is approximately 0.50 to 0.125 angstrom units (Figure 1).

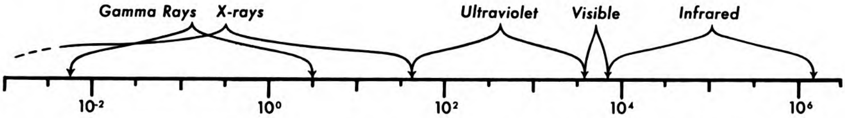


FIGURE 1—Short wave length radiation (in angstrom units, 1A = 10^{-8} cm.).

X-rays exhibit all of the properties of visible light. For example, light is refracted by glass and, consequently, is capable of being focused by a lens in such instruments as cameras, microscopes, and so forth. X-rays are also refracted, but to such a very slight degree that it requires the most refined experiments to detect this phenomenon. Hence, the use of any kind of lens is quite out of the question. Other similarities between x-rays and light may be noted but, for the most part, the effects produced are so different that it is preferable to consider the properties of x-rays separately from other types of radiation.

When lengthy exposures are employed, x-rays have the power to change the color of many chemicals by altering the atomic structure, e.g., salt turns yellow from liberation of chlorine. Another important characteristic is the ability of x-rays to excite fluorescence in many substances, such as barium platinocyanide, zinc sulfide, and calcium tungstate. This activity makes possible the use of fluoroscopic and intensifying screens for fluoroscopy and for reducing the x-ray exposure in radiography. Therapeutically, x-rays are a powerful agent in the treatment of cancer and other lesions. Air can be ionized by x-rays — a principle employed in the *r*-meter or ionization chamber for measuring x-radiation.

Electrical Terms

Radiographic exposure factors are usually expressed in electrical terms. Electricity, like water, is capable of flowing through a conductor, and

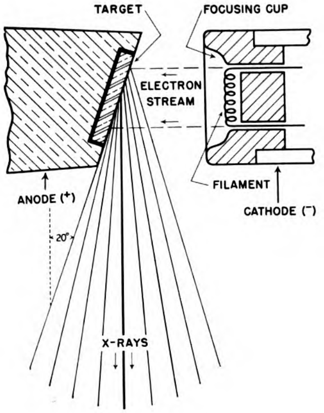


FIGURE 2—Schematic diagram of the generation and bombardment of electrons from a heated filament in the cathode of an x-ray tube and subsequent production of x-rays from the focal spot of the anode.

this flow or *current* is measured in *amperes*. However, the ampere is too large a unit to employ in radiography, and the *milliampere* (1/1000 ampere) is used instead. For electricity to flow, it must be under pressure; the unit of pressure is the *volt*. Thousands of volts are required when making exposures and the term usually employed is the *kilovolt* (1000 volts). The number of amperes or volts respectively does not indicate the amount of power in a circuit; however, when volts and amperes are multiplied, the product is the unit of power called the *watt*. Thousands of watts are used by x-ray apparatus; therefore, the term *kilowatt* (1000 watts) is more commonly employed.

The *roentgen (r)* is the international unit of quantity for both x-rays and gamma rays. It was adopted by the Fifth International Congress of Radiology, in 1937. The definition of the *roentgen* given by the International Committee for Radiological Units is as follows:

> The International Unit of quantity or dose of x-rays or gamma rays shall be called the *roentgen* and shall be designated by the symbol *r*. The roentgen shall be the quantity of x- or gamma-radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 esu of quantity of electricity of either sign.

Tubes

The manner in which x-rays are generated is a complex physical process. Fortunately, a knowledge of only a few of the basic principles is necessary. The essential feature of x-ray production is the striking of matter by high-speed electrons; this may occur within or outside a vacuum. Basically, the device in which x-rays are generated is the x-ray tube. X-rays are produced in an x-ray tube when electrons, traveling at great speed in a high vacuum, under stress of high voltage, collide with a tungsten target. The efficiency of production of x-rays is very small, for only about one part in a thousand of electron energy at average kilovoltages is converted into x-rays that are penetrating enough for radiography.

An x-ray tube consists of a highly evacuated glass bulb into which are sealed two electrodes—the cathode, or *negative* electrode (the source of electrons), and the anode, or *positive* electrode. The degree of vacuum of the x-ray tube and the arrangement of the electrodes are such that no electrical discharge between the cathode and the anode is possible until the filament of the cathode is heated. Employing the principle that all *hot* bodies emit electrons, a spiral, incandescent filament of tungsten wire is incorporated in the usual form of x-ray tube (Figure 2). The filament is heated to incandescence by about 4 amperes of current from a low voltage step-down transformer. The temperature of the filament, as governed by the magnitude of the current that passes through it, controls the *number* of electrons emitted—the higher the filament temperature, the greater the electron emission. The stream of electrons from cathode to anode constitutes the tube current and is measured in *milliamperes* by a milliampere meter.

Surrounding the filament is a shield terminating in a cup that serves to focus the electron stream from the heated filament to the *focal spot* on the end of the anode. Varying the distance between the focusing cup and the anode affects the size of the focal spot. The shape of the filament also determines the focus, whether small, medium, or large. The electron stream is propelled by a high voltage impressed on the tube electrodes by a high-voltage transformer. This voltage, which may be varied at will, regulates the speed with which the electrons cross the gap between the cathode and anode. Upon impact with the focal spot of the tube, the electrons give rise to a stream of x-rays which are emitted over a 180° hemispherical angle surrounding the focal spot of the target. Only a fraction of these x-rays passes through the portal of the tube.

Despite the enormous energy in the electron stream, only a small portion is effective in the production of x-rays; the bulk is dissipated as heat through the anode. The greater the force of impact of the electrons on the focal spot, the shorter the wave length of the x-rays and the more readily do they penetrate the object being examined.

As will be seen later, different voltages are applied to the x-ray tube to meet the demands of various classes of radiographic work. The higher the voltage, the greater the speed of the electrons striking the focal spot. The result is a decrease in wave length of the x-rays emitted and an increase in both their intensity and penetrating power. It is to be noted that x-rays produced, for example, at 80 kilovolts contain all of the wave lengths that would be produced at 60 kilovolts. In addition, the 80-kilovolt x-rays include some shorter wave lengths not present in the 60-kilovolt radiation.

The anode of the line-focus stationary-anode tube is usually a solid bar of copper, with the end facing the cathode cut to form an angle of 20°. The angulation of the anode face affects the size of the focal spot. The actual target, generally a rectangular block of tungsten, is set into the oblique anode face, and x-rays are produced when it is bombarded by the stream of electrons from the cathode. Nearly all the energy applied to the x-ray tube is transformed into heat at the focal spot — the area of electron bombardment on the target. This heat is dissipated largely through the anode stem, a copper bar fused into and protruding out of the glass envelope of the tube.

The high concentration of heat in a small area, such as the focal spot, imposes a severe burden on the materials and design of the anode. The efficiency of the focal spot material in the production of x-rays is proportional to its atomic number. The high atomic number of tungsten, in combination with its high melting point, makes it the most suitable material for the focal spot of an x-ray tube.

Three means of cooling the anode stem are used. In the "radiator" (air-cooled) type of tube, the heat is conducted through the stem to a series of radial fins outside the glass bulb. In the water-cooled type, a reservoir is used, from which tubing leads into the stem of the anode, providing a means for circulation of the water. In the oil-immersed type, oil is the medium employed for cooling the anode. Owing to the high heat capacity and conductivity of the copper bar and the effectiveness of the cooling system, the heat generated at the target is dissipated very rapidly.

Tube Types There are two types of tubes: the stationary-anode tube and the rotating-anode tube. The stationary-anode tube is the conventional type that has been most extensively used. The limitations of the stationary-anode tube have been largely overcome in the rotating-anode tube (Figure 3) which permits the use of a much smaller focal spot for a longer period of time, or the application of a higher energy for short exposures. In this type, the position of the focal spot remains fixed *in space* while the anode revolves throughout the exposure to provide continually a fresh surface for the bombardment of the electron stream that is focused on an area of the anode some distance away from the center of rotation. Thus, the energy is distributed over a broad ring and, for the same exposure conditions, the focal-spot area is only one sixth (or less) that required in the stationary-anode tubes. The slope of the anode face is usually 15°.

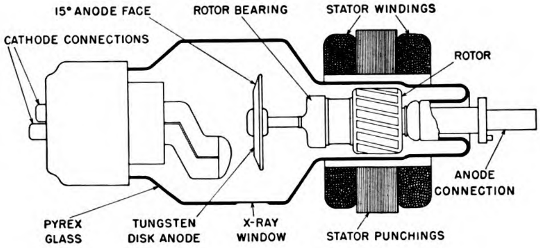


FIGURE 3—Diagram of rotating-anode tube.

Tube Capacity X-ray tubes are classified by the manufacturer according to the size of the focal spot — the smaller the focal spot, the less the energy that can be applied without damage and the sharper the definition. A tube having a large focal spot is capable of withstanding very high energies, but definition suffers. Both stationary- and rotating-anode tubes are available in a variety of focal-spot sizes. In addition, both types of tubes are manufactured with one or two focal spots and are known, respectively, as single-focus and double-focus tubes. Tube capacity is based on the maximum heat that the focal-spot area permits, the rapidity with which the heat can be dissipated, and the mechanical design. Long or careless usage will roughen and form pits in any focal-spot surface, resulting in lowered x-ray output and impairment of definition.

The manufacturers of x-ray tubes furnish rating charts indicating the kilovoltages and milliamperages that may safely be applied for the various exposure times. The life of any tube will be prolonged considerably if it is always operated within the rated capacity.

Focal Spot The tube focal spot from which the x-ray beam emanates should be as small as conditions permit in order to secure the sharpest possible definition in the radiographic image. A focal spot of small effective size, though the actual focal area on the anode face may be fairly large, is provided by the principle of the line focus (Figure 4). By making the angle between the anode face and the central ray small, usually 20°, the effective area of the spot is only a fraction of its actual area. With the focal area in the form of a long rectangle, as shown, the projected area is square in the direction of the central ray. The focal spot has different effective sizes for x-rays emitted at different angles from the target (anode) face. In the long axis of the tube, the projection of the focal spot is much smaller than the actual focal spot dimension. The projection of the focal spot at the cathode end of the beam approaches the original size. On a single radiograph, that portion of the image projected by the anode end of the beam is sharpest in definition, while the definition at the cathode end is less sharp.

The form and size of the focal spot of an x-ray tube may be easily determined by the method of pinhole radiography, which is identical in principle with pinhole camera photography. A thin lead plate containing a small hole is placed midway between the focal spot and the film so that the hole is in the path of the central ray. The resultant image is then equal in size to the focal spot. A focus-film distance of 24 inches is usually convenient. The exposure time is much greater than is needed for blackening the film without the plate, because very little radiation can pass through the small aperture. The image can be *perfect* only if the hole is a geometric point, but a needle or a No. 60 drill will make a hole small enough for practical purposes.

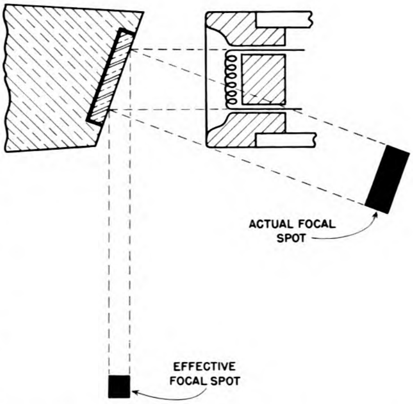


FIGURE 4—Diagram of a line-focus target depicting relation between actual focal spot (area of bombardment) and effective focal spot, as projected from a 20° anode.

Circuits

X-ray equipment operates on either 110-volt or 220-volt alternating current. The action of the apparatus can be better understood if a typical circuit is traced. For this purpose, the schematic labeled diagram of a typical x-ray generating circuit shown

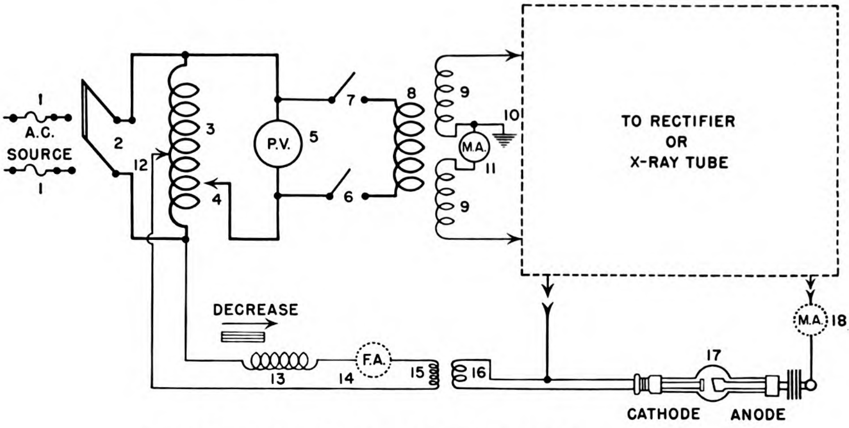


FIGURE 5—Diagram of circuit common to most x-ray generators.

LEGEND:

1. Fuses
2. Line switch
3. Autotransformer
4. Autotransformer control
5. Primary voltmeter
6. Circuit-breaker
7. Timer
8. Primary of x-ray transformer
9. Secondary of x-ray transformer
10. Ground
11. Low-tension milliammeter
12. Filament-circuit connector
13. Filament control
14. Filament ammeter
15. Primary of filament transformer
16. Secondary of filament transformer
17. X-ray tube
18. High-tension milliammeter

in Figure 5 is sufficient to demonstrate its basic features.

Transformers

Three types of transformers are usually incorporated in apparatus employed for the generation of x-rays.

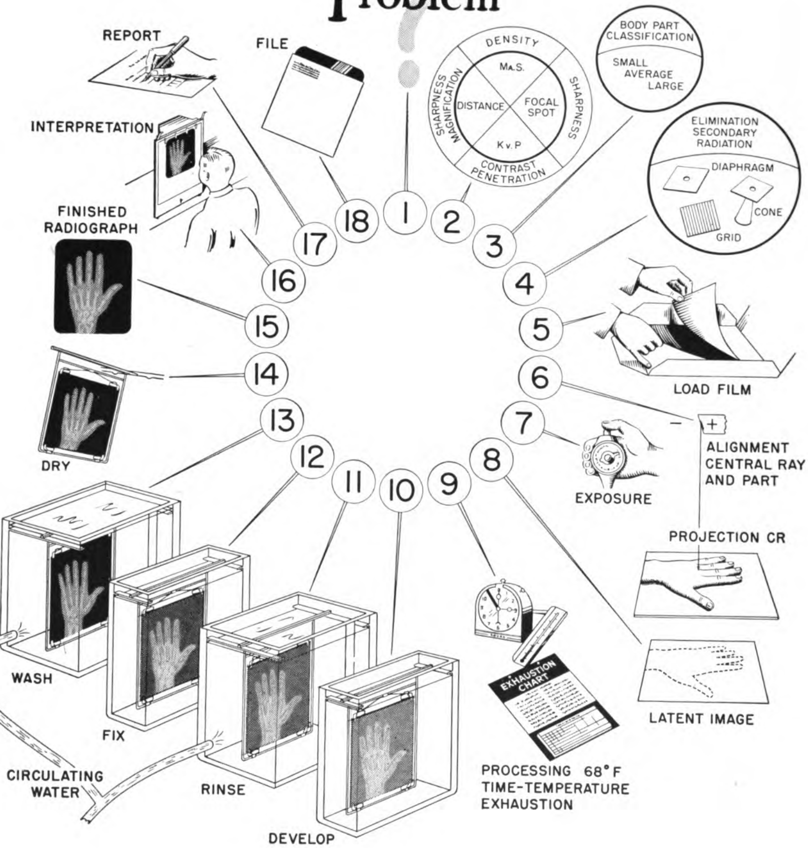
The *autotransformer* (3, Figure 5) or voltage selector consists of a single winding. Its function is to vary or control the voltage impressed on the primary coil of the high-voltage transformer.

In the *step-up*—x-ray—transformer (8 and 9), which provides the high voltage necessary for the generation of x-rays, the primary coil connected to an alternating current source through the autotransformer has relatively few turns of wire; the secondary coil is energized by induction from the primary coil and consists of a great number of turns. The ratio of the voltages across the primary and secondary coils varies directly as the ratio of turns. The current, however, varies *inversely* as the ratio of turns. For example, if there are 10 turns in the primary coil and 10,000 in the secondary, an impressed voltage of 100 volts on the primary side would induce 100,000 volts in the secondary circuit, with a decrease in amperage.

The *step-down*—filament—transformer (15 and 16) is similarly constructed except that the relative positions of the windings are reversed so that the voltage impressed on the primary is reduced in the secondary coil and the amperage is correspondingly increased. It is used as a means of heating the filaments of the x-ray tube and the rectifier tubes employed in various types of rectification.

Rectification The current in the secondary coil of the high-voltage transformer is high-tension alternating current, and as unidirectional current is necessary for the production of x-rays, some means of changing—rectifying—this current to high-tension pulsating direct current must be employed. This may be accomplished in three ways: by the rectifying action of the x-ray tube itself; by one or more thermionic vacuum tubes known as valve tubes or rectifiers inserted in the line; or, in some older types of equipment, by a mechanical switch operated by a synchronous motor. The various types of rectification are called self rectification, half-wave rectification (single-valve-tube), full-wave rectification (mechanical), full-wave rectification (four-valve-tube), and three-phase rectification (six-valve-tube).

Problem



Steps in the production of a radiograph.

Recording the Image

• Uniformity in radiographic quality is an ideal that should be sought by every technician. Technical procedures are often employed that do not attain this ideal, due largely to a lack of suitable understanding concerning the function of each exposure factor and its resultant radiographic effect. The correct application of exposure factors is dependent upon *how* the technician thinks regarding them. If the function of each exposure factor is understood, a radiograph that is diagnostically acceptable and of satisfactory technical quality can be readily made.

X-ray film is the recording medium for the radiographic image. A radiographic image is a pictorial record of the internal structure of an object or part of the body as projected by x-rays on an x-ray film. It is produced when a traversing x-ray beam exposes the film with radiation that has been selectively diminished in intensity by absorption by the material or tissue of the subject; subsequent processing of the film reveals the image and the film is then known as a radiograph. Absorption differences in body thicknesses and densities are rendered on the radiograph as differences in radiographic density or contrast. The following text explains the terms normally employed in describing a radiograph.

The radiograph comprises what is more commonly known as radiographic *detail* that is composed of a multitude of deposits of black metallic silver *(radiographic densities)* of varying translucency to the light of an x-ray illuminator. In other words, radiographic detail constitutes the image. The *definition* of the image is the degree of sharpness of the outlines of the detail.

Individual silver deposits (densities) have light-translucency values known as *tones.* The varying *degrees* of radiographic density or silver concentration of each tone are due to the variable intensities of radiation (remnant radiation) emerging from the tissues that exercise selective absorption of the primary beam. These differences in density enable image details to become visible and constitute radiographic *contrast.*

The inherent characteristics of an x-ray film determine its influence on the contrast of the radiograph and the degree to which the film is able to convert an x-ray exposure into radiographic density when standardized processing is employed. The quality of the radiograph is also affected by the exposure factors of kilovoltage (KvP) and milliamperage (MA) and duration of exposure in seconds (S). When multiplied, the MA and S constitute the milliampere-seconds (MAS) factor.

Kilovoltage influences both radio-

graphic contrast and density. However, when a fixed kilovoltage is employed for a given part, it is considered as a constant, and changes in radiographic density are made only by milliampere-seconds. The kilovoltage influences the wave length of the generated x-rays and the wave length in turn determines the penetrating power of the radiation. Kilovoltage is also a factor in the production of secondary radiation. The focus-film distance not only influences the radiographic density but also the sharpness of the image.

Radiographic Density

Radiographs are commonly viewed before an illuminator which transmits light of normal intensity. The amount of silver on the radiograph determines the translucency of the image to the transmitted light. To be diagnostically useful, *all* densities should transmit some visible light (be translucent) and, if possible, every portion of the image should contain some silver deposit. Assuming that the radiograph is processed by the time-and-temperature method, heavy, opaque deposits are known as *overexposures* (Figure 6A). Areas of the image possessing little or no silver are almost totally transparent and are known as *highlights* or local *underexposures* (Figure 6B). Highlights, being devoid of silver, and, therefore, of detail should be avoided unless they happen to be diagnostically acceptable. Under average illumination, areas of overexposure are also diagnostically useless since the opaqueness of the silver deposit obscures detail. Figure 6C is a properly exposed radiograph in which the **faults found in radiographs 6A and 6B have been overcome.**

The density of the radiograph is influenced by the quantity of radiation that reaches the film. The amount of primary radiation is regulated by the quantity of current in milliamperes (MA) flowing through the tube for a definite length of time in seconds (S). When a fixed kilovoltage is employed, the radiographic density may be regulated by either increasing or decreasing the MAS to its correct value so that the remnant radiation will be sufficiently intense to produce a satisfactory image.

The use of the exhaustion method (page 77) or the replenisher method (page 82) of standardized development produces the most satisfactory radiographs. When these methods are not employed, the density of the film may be affected by any variation in the time or temperature of development. When standardized processing is employed, the radiographer may obtain any degree of radiographic density by control of the MAS factor. Processing should then be considered as a constant.

Individual radiographic densities or tones vary, one from another, since they differ in their degrees of silver concentration and, therefore, translucency to the light of the illuminator. The translucency of the density, or tone value, is dependent upon the amount or quantity of radiation reaching the film after passage through the tissues being examined. Due to the absorption characteristics of the tissue, the resulting *remnant* radiation varies greatly in intensity, as compared to the primary radiation before it enters the part examined.

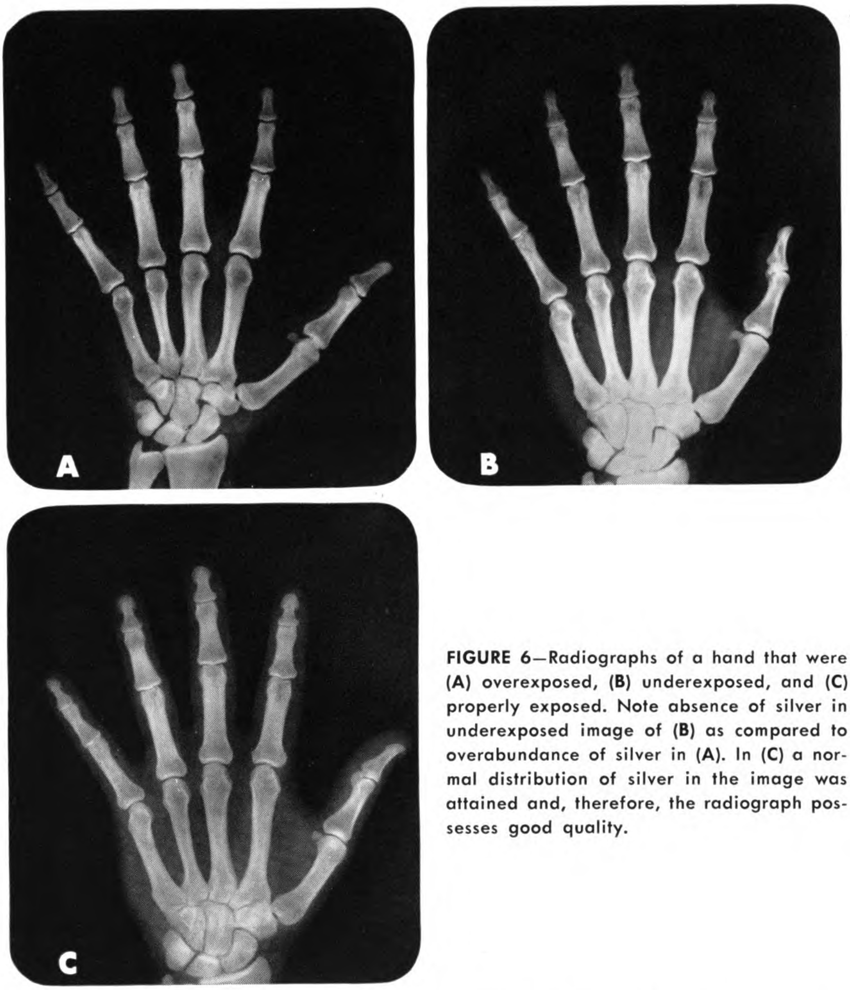


FIGURE 6—Radiographs of a hand that were (**A**) overexposed, (**B**) underexposed, and (**C**) properly exposed. Note absence of silver in underexposed image of (**B**) as compared to overabundance of silver in (**A**). In (**C**) a normal distribution of silver in the image was attained and, therefore, the radiograph possesses good quality.

It is these varying intensities within the remnant radiation that produce the various tones or densities on the film that constitute the image.

The radiographic density produced by the remnant radiation is adversely affected by *supplemental* densities or fog. For example, in the various stages of handling x-ray film in storage, exposure, and processing, it may be subjected to many physical and chemical accidents that may produce fog on the radiograph. The presence of various types of fog must be recognized by the radiographer if good quality in the radiograph is to be secured, for it increases the over-all density of the radiograph. Fog may be defined as a local or generalized veiling of the image detail by a supplemental deposit of silver resulting from extraneous physi-

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cal, chemical, or exposure causes. The types of fog most commonly encountered are secondary radiation fog, chemical fog, age fog, and light fog. With the exception of that produced by secondary radiation, fog may be reduced to a minimum by the proper storage, handling, and processing of film.

Radiographic Contrast

Kodak x-ray film, processed according to recommendations, possesses an inherent contrast scale most suitable for radiography. The developing solution provides a scale of contrast characteristic of its formula when compounded properly and functioning at an optimum temperature. In other words, the contrast scale in the radiograph is a combination of those contrasts that are inherent in the film and the developer, plus whatever changes may be made in the contrast of the subject scale through the medium of kilovoltage. When time-temperature processing is employed in accordance with the activity of the solution calculated by developed film areas, or with replenishers, the radiographer need concern himself only with the contrast that can be controlled by the kilovoltage. In the interest of standardization, inherent film and developer contrasts are accepted as constants. Therefore, any changes in contrast so far as this discussion is concerned are related only to changes effected by kilovoltage (Figure 7).

Radiographic contrast in a fully exposed image may be defined as the characteristic that permits differentiation to be made between densities and thus visualization of image detail. The over-all density of the image must be such as to reveal *all* essential detail of the structures examined before it can be said that optimum contrast is present. Full penetration of the part is necessary to achieve this condition. In other words, optimum contrast makes possible the visualization of all image details within a given part that are rendered throughout the full diagnostic range of translucent densities or tones.

General differences in tone value may be divided for convenience into two arbitrary scales of contrast. It may be said that as radiographic contrast *increases,* the brightness differences in tone value between adjacent densities become greater or more abrupt. The densities that represent the thinner portions of the part increase and may become opaque. This increase may be carried to excess so that the densities which represent the thick parts become very low, to the extent of not recording detail at all. Visibility of detail in those areas is diminished and *short-scale* or high contrast results. The image records only a small range of densities (middle tones) within the part examined, depending upon the amount of penetration occurring.

As radiographic contrast *decreases,* the brightness differences in tone value between densities become less; consequently, a greater number of tones are visualized over the entire image. The transition between tones is gradual since only small density differences occur. This type is known as *long-scale* or low contrast.

To illustrate types of contrast, two radiographs of the knee will suffice.

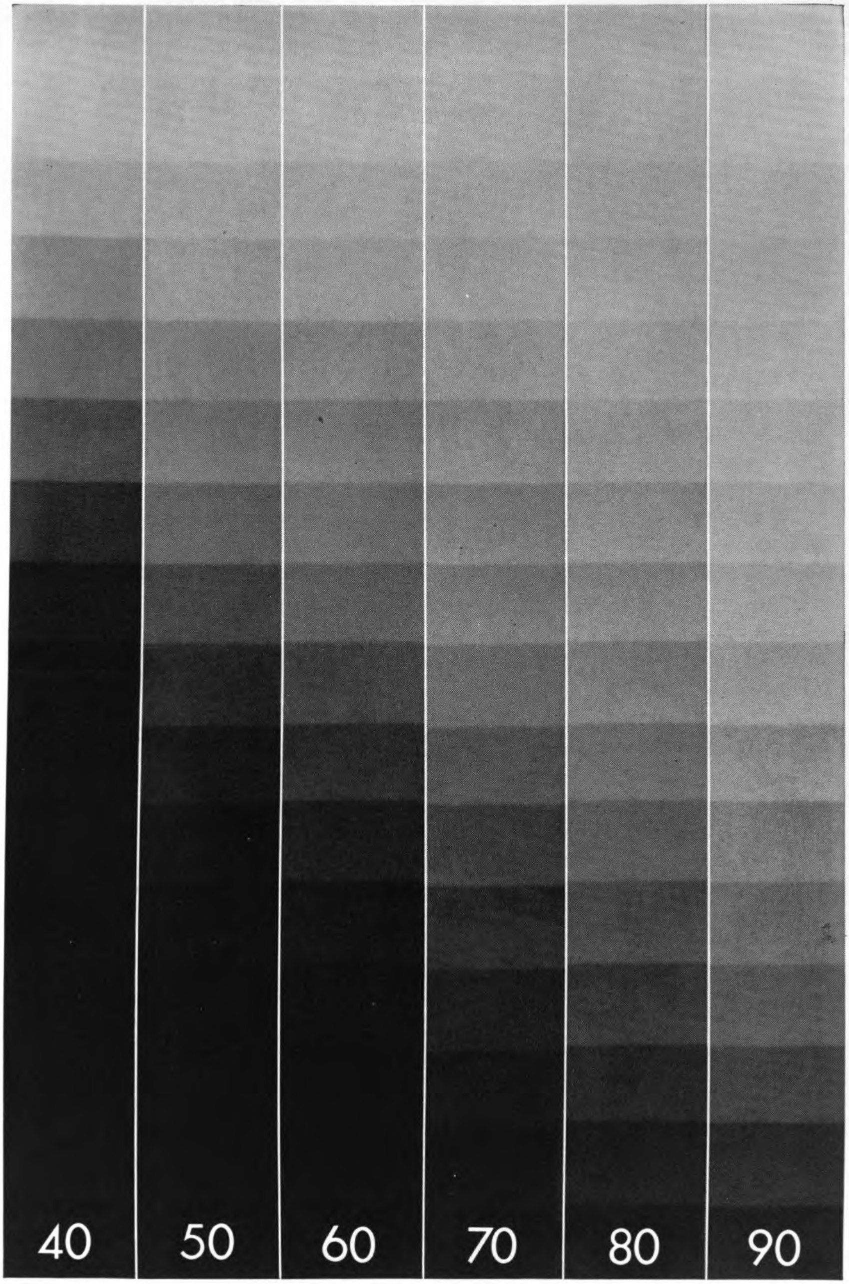

FIGURE 7—Step-wedge radiographs made with kilovoltages of 40 to 90 which demonstrate the radiographic influence of kilovoltage on contrast. Note that the lower kilovoltages produce short-scale contrast; the higher kilovoltages produce the long-scale contrast that is so desirable in medical radiography.

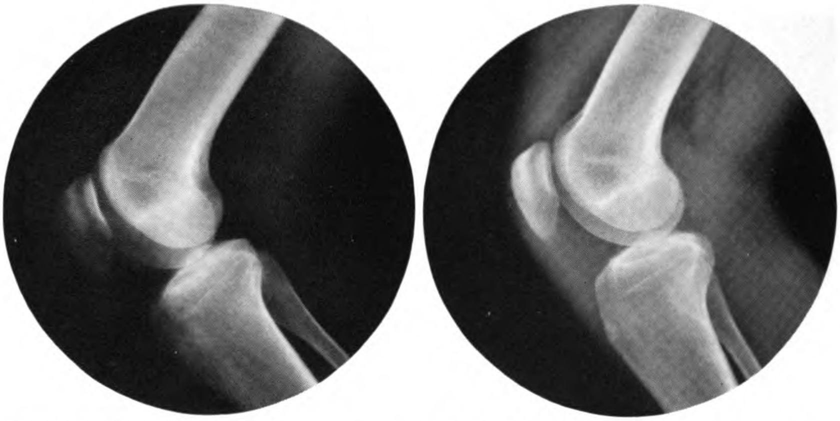

FIGURE 8—Radiographs of a knee made to illustrate types of contrast. **LEFT:** Demonstrates short-scale contrast. **RIGHT:** Demonstrates long-scale contrast.

The first radiograph (Figure 8, left) "catches" the eye at once because the gross details are outstanding; it is easier to look at and the eye has to contend only with a few image details. The second radiograph (Figure 8, right) does not have quite as distinctive "eye appeal" as the first radiograph because of its lesser brilliance. However, a larger number of details have been introduced into this lower-contrast image, although they may be a trifle more difficult to see. This requires that the eye more carefully scan the image for essential details.

One might assume that the image in the first radiograph is revealed with sharper definition than in the second but this is not true since the same geometric qualities exist in both images, that is, the focal spot of the tube and the focus-film distance were the same for both. Fewer details are to be seen in the first radiograph because of local opacities and highlights. In the second radiograph, on the contrary, detail is visible in practically the *entire image.*

The most desirable contrast scale rests between these two examples depending upon the choice of the radiologist. Initial radiographs of a part may be considered as normal films and should possess medium or optimum scale contrast. When a small portion of a specific part is to be reexamined for further study, exposures can be made with less kilovoltage simply to increase the brightness differences and make the details of interest more outstanding.

Exposure Latitude An important bearing on radiographic contrast is the film characteristic *exposure latitude* (Figure 9). Film latitude is that exposure spread or interval between the least and the largest exposure that will produce a reasonably satisfactory image. Film latitude, to be effective, is dependent upon the scale of radiographic contrast which in turn is regulated by the kilovoltage employed. Latitude is small when low kilovoltages are employed because of the short-scale contrast pro-

duced in the image. Wide exposure **latitude** is secured when the higher-than-average kilovoltages that produce long-scale contrast are used. It is this exposure characteristic that makes possible large differences in MAS values to compensate for tissue thicknesses when employing fixed kilovoltages.

Up to this point emphasis has been placed on those factors that produce good-quality radiographs. The question arises as to how critical these factors are and how great a mistake can be made in the exposure technic without losing diagnostic value. The greater the exposure error that can be tolerated, the greater is the "latitude" of the radiographic procedure.

The following general rule may

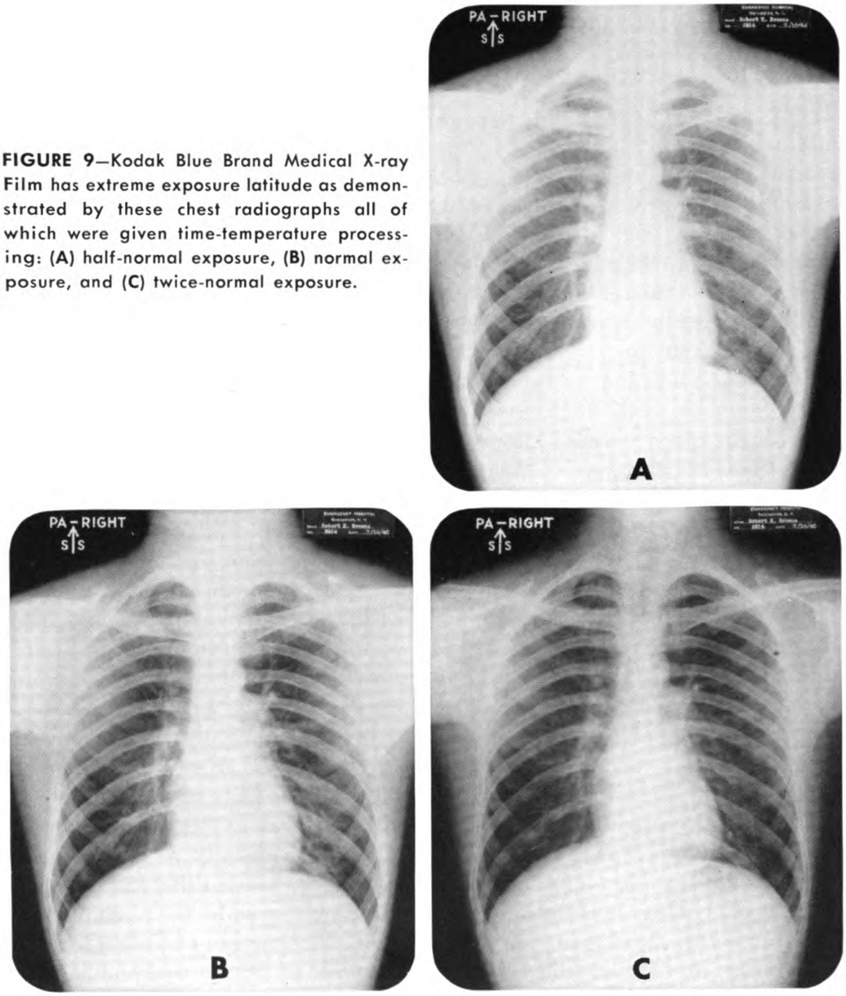

FIGURE 9—Kodak Blue Brand Medical X-ray Film has extreme exposure latitude as demonstrated by these chest radiographs all of which were given time-temperature processing: (**A**) half-normal exposure, (**B**) normal exposure, and (**C**) twice-normal exposure.

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be considered basic: *The longer the scale of contrast in the radiograph, the greater is the latitude.* Therefore, a radiographer operating with a constant, higher kilovoltage technic is more likely to produce greater uniformity of radiographic quality than one who uses a relatively low, variable kilovoltage technic. In fact, the latitude that is available at the higher kilovoltages is the very factor that permits consistency in results obtained with fixed kilovoltages.

X-ray Absorption

The x-ray beam is composed of a mixture of wave lengths. This characteristic causes various wave lengths to be absorbed in varying degrees by the material or part irradiated. The longer their wave length, the more readily are the x-rays absorbed, while the shorter wave lengths are able to penetrate the part and emerge as *remnant* radiation to expose the film.

With any given material, the greater its thickness and weight, the more will the x-rays be absorbed, permitting less to pass through and reach the x-ray film. Different kinds of material of the same thickness absorb x-rays in different degrees. Bone, for example, will absorb more x-rays than an equal thickness of flesh (soft tissue). This is due in part to the fact that bone is a heavier or denser material than flesh, since calcium is its chief mineral constituent. Atoms of higher atomic number have greater x-ray absorption than atoms of low atomic number. Most of the metals have higher x-ray absorption than flesh or bone. Lead has especially high x-ray absorption and for that reason is used widely as an x-ray protective material.

As the primary x-ray beam passes through a part of the body, various portions of the beam are absorbed in proportion to the density of the tissue, and the intensity of the primary radiation is selectively diminished. The emergent or unabsorbed *remnant* radiation is no longer uniform in intensity as it passes to the film, so the emulsion is affected in accordance with the varying intensities within this remnant beam. As a consequence, the variance with which the emulsion is affected determines the variance with which the exposed emulsion is reduced by the developing solution to form the varying radiographic densities in the image. The greater the tissue absorption, the less intense is the remnant radiation which can affect the film in recording the image. A relationship, therefore, exists between *tissue absorption* and *radiographic density.*

The relative x-ray absorbing power of an object or body part may be easily studied by employing a simple test object such as an aluminum step wedge. The wedge is placed on an x-ray film, an exposure is made with low kilovoltage, and an image of several steps of the wedge is recorded on the film. This is diagrammatically shown in Figure 10.

Inspection of the image reveals the degree of absorption that occurred with respect to each step of the wedge as evidenced by the differences in density of each *tone* in the image. These differences in tone value are caused by the remnant radiation. The portion of the radiograph not covered by the wedge exhibits a dense silver deposit, since it was exposed by the unabsorbed primary radiation. The first step of the wedge offered very little resistance to the passage of the x-rays and the area of film covered by this step appears nearly black or opaque. The second step is recorded as a dark-gray tone in the image indicating that the remnant radiation reaching the film was less than in the case of the first step. The second step, therefore, can be said to have absorbed more radiation than the first step, because of its greater thickness or power of absorption. The third and fourth steps are recorded as light-gray tones, indicating that more radiation was absorbed by these thicknesses. The fifth step and the balance of the wedge absorbed most of the radiation, and the image of this portion is rendered with very little silver deposit.

It may be seen from this example that the difference in absorption of each step of aluminum had a direct relationship to its respective radiographic density. Since each step of the aluminum wedge was uniform in its "tissue" absorption, uniform radiographic densities resulted. Each thickness or step of the wedge is represented by a radiographic density with a definite tone value, the amount of silver deposited being related to the amount of remnant radiation reaching the emulsion in that area. The wedge, then, is radiographically represented simply as a series of tones of varying density. From this image, only a partial idea as to the general nature of the object examined could be secured because of the lack of penetration by x-rays of the entire wedge.

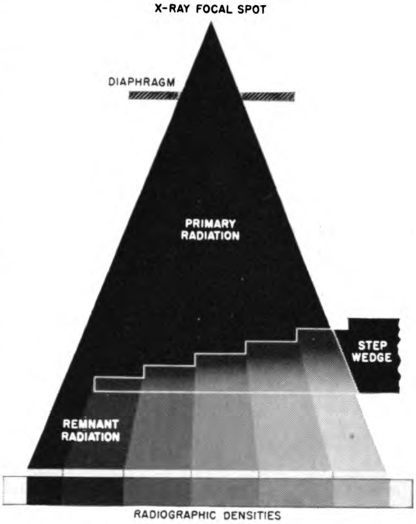


FIGURE 10—Diagram that illustrates passage and absorption of an x-ray beam by an object of homogeneous density.

The absorption characteristics of an object containing a small cavity are diagrammatically shown in Figure 11, page 24. There is less material capable of absorbing x-rays in the area of the cavity than in the other areas. Therefore, less x-rays are absorbed while passing through this vacant area and the resulting remnant radiation from this area is greater than that from the balance of the object. Consequently, the increased intensity causes more silver to be affected in the emulsion, and a distinctive radiographic density appears which can be interpreted as a cavity in the object.

A part of the body composed of a complex tissue structure, such as the leg, can also be recorded as an image in which the tone values of the various radiographic densities are representative of the tissues traversed.

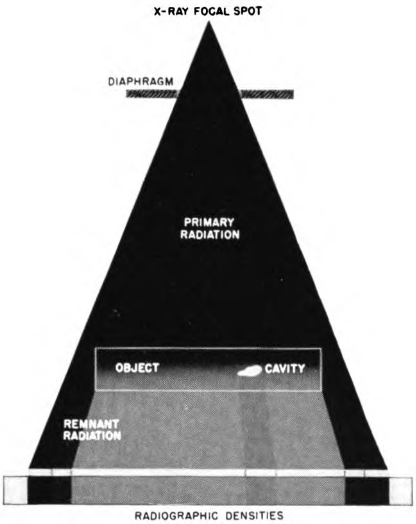


FIGURE 11—Diagram that illustrates passage and absorption of an x-ray beam by an object of homogeneous consistency containing a cavity. Few absorbing elements are present.

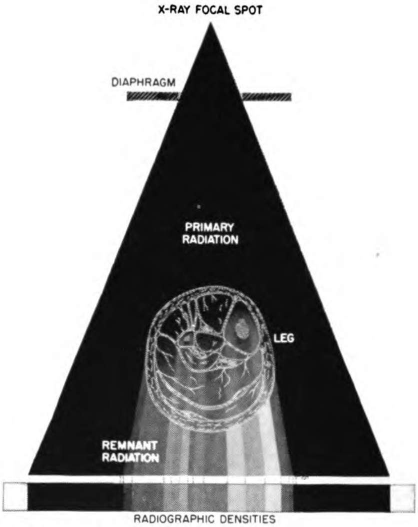


FIGURE 12—Diagram that illustrates passage and absorption of an x-ray beam by a human leg containing a multiplicity of elements that have various powers of absorption of x-rays.

As is shown in Figure 12, when primary x-rays pass through the leg, the components or individual elements such as bone, flesh, and so forth, absorb the x-rays in varying degrees, depending upon their absorption characteristics. Bone absorbs more x-rays than flesh; flesh, more than air; normal flesh and bones, more than those that have been atrophied or debilitated by disease; and adult tissue absorbs more x-rays than that of a child.

As was indicated with the wedge, it was possible to differentiate between the various thicknesses of metal simply by comparing the densities in the image when penetration occurred. This also can be accomplished in radiography of the leg; the primary beam passing through the part is absorbed in accordance with the absorption of its components. These variations in absorption are depicted in the image as radiographic densities of varying tone value. The relative absorption of each step in the wedge is indicated by various densities or tones and the same holds true with the leg wherein the components of the tissues are recorded in the image as radiographic densities of diverse tone value.

The significance of the absorption and physiology of human tissue must be recognized with respect to its correct radiographic rendition. Any alteration of the exposure factors must be made on the foregoing basis in order to secure proper radiographic quality.

Kilovoltage

The influence of the kilovoltage on absorption of the part is a most important factor in considering the exposure. The kilovoltage applied to the tube has a direct influence on the *qualitative* characteristics (wave length) of the x-ray beam and determines the penetrating power of the radiation. Kilovoltage governs the scale of contrast in the image, as previously discussed, and influences the production of secondary radiation.

Depending on the manner in which they are produced, x-rays have wide variations in their ability to penetrate matter. The radiation emitted by an x-ray tube contains a mixture of wave lengths (a continuous spectrum). When a high kilovoltage is applied to the x-ray tube, the radiation has a greater proportion of short wave-length x-rays resulting in a beam of greater penetrating power. As such a beam passes through matter, the longer wave lengths are largely absorbed, or "filtered out," and the shorter wave lengths pass through with some loss of intensity. Low kilovoltage produces long wave-length x-rays having low penetrating power. When an x-ray beam is capable of penetrating a specific body part irrespective of its thickness, the wave length of the x-rays is said to be satisfactory (optimum). Higher kilovoltage will serve only to reduce contrast beyond the useful limit and introduce some measure of secondary radiation fog. In other words, an optimum or fixed kilovoltage employed for a given part assures the production of a sufficient amount of short wave-length x-rays in the remnant beam to produce a satisfactory radiographic image.

Employing an *optimum* or *fixed kilovoltage* technic makes possible a reduction in the number of kilovoltages needed for radiography of the entire body. There is little appreciable or useful advantage in small kilovoltage changes in routine medical radiography. Higher or lower kilovoltages may, of course, be employed advantageously in exceptional instances, but such discussion is not within the scope of this text.

Too often low kilovoltages are employed in radiography with unsatisfactory results. The many highlights produced in the radiograph are devoid of image detail and diagnostic usefulness is limited. Highlights often indicate that the x-rays had insufficient penetrating power and that the quantity of remnant radiation was insufficient to record detail in these areas. Mistakenly, the MAS is often increased to offset this lack of penetration, but it is usually a futile operation for, despite impractical and lengthy exposures, no appreciable quantity of radiation will pass through the part unless the wave length is shortened by the use of a higher kilovoltage. No *practical* amount of MAS, therefore, can compensate for inadequate penetration (kilovoltage).

For example, assume that a small unit of an x-ray beam created by low kilovoltage enters a thick part (Figure 13A, page 26). It cannot penetrate the part sufficiently to affect the film as remnant radiation in a practical length of time, because it is largely absorbed. If this x-ray beam had a wave length impressed by a higher kilovoltage sufficiently short to permit a greater portion to penetrate the part and emerge as remnant radiation, it would then affect the film as a usable radiographic density (Fig-

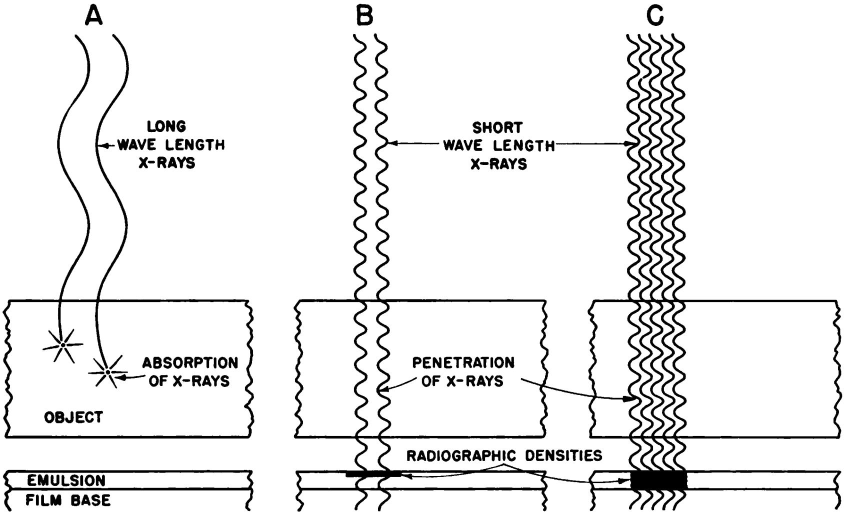


FIGURE 13—Diagrammatic representation of penetrating power of x-rays. (A) X-rays of long wave length absorbed by object; (B) x-rays of short wave length penetrate object and as remnant radiation, expose the film; (C) increasing the number of x-rays by the MAS factor increases the amount reaching the film and more silver in the film is exposed than in (B).

ure 13B). If the amount of x-rays was increased by raising the MAS, a greater radiographic density would appear on the film (Figure 13C). As heretofore mentioned, the *kind* or *quality* of radiation is governed by the kilovoltage, and the *quantity* of x-rays is controlled by the MAS. Therefore, when the quality of radiation is established by an optimum or fixed KvP for a particular part, and established as a constant, the density of the image may be controlled by the MAS.

Secondary Radiation When a primary beam of x-rays penetrates an object, some of the x-rays are absorbed and some pass directly through; a considerable percentage, however, is scattered in all directions by the atoms of the object struck, very much as light is dispersed by a fog. These scattered rays comprise what is known as *secondary radiation* and possess a longer wave length than that of the inciting *primary* beam. Since the x-rays that are thus deflected from their path are radiographically effective, they cause a general haziness or fog on the film. Secondary radiation must be considered objectionable to good radiographic quality, for it overcasts the image with a *supplemental* density and obscures image detail. Since secondary radiation originates from a multiplicity of sources, it is not possible to control it completely. Therefore, it must be eliminated or reduced to an unobjectionable quantity. The additional density superimposed by secondary radiation fog upon the radiograph serves to increase the over-all density of the image and to reduce ability to see radiographic detail clearly.

As kilovoltage is increased, there is a corresponding increase in the production of secondary radiation. This may be 4 to 10 times as intense as the primary beam itself. The abundance of this unfocused, aberrant radiation exposes x-ray film and can be most objectionable to good radiographic quality unless effective means for its control are exercised. The use of cones, aperture diaphragms, grids, and so forth, can reduce secondary radiation to the point where it does not adversely influence the diagnostic value of the radiograph. The problem of secondary radiation fog is minor in radiography of thin parts, but when thicker parts are radiographed, those measures available for limitation of the amount of secondary radiation reaching the film must be employed. Attempts to use low kilovoltage as a means of controlling the amount of secondary radiation fog usually result in the use of x-rays with too low a penetrating power.

The higher the kilovoltage, within certain limits, the greater the efficacy of the radiation because of the certainty of penetration. When the kilovoltage is too high, it has a tendency to penetrate the part without sufficient differential absorption by the tissues, and the very long contrast scale in the image tends to be destroyed in part by the production of an excessive amount of secondary radiation generated from adjacent body areas or equipment.

When radiographic tables with wooden or plastic tops are used in direct-exposure technics, secondary radiation is directed back to the film which makes necessary the interposition of a thin sheet of lead between the film and the table. Because of this phenomenon, a lead sheet is incorporated in the back of devices that hold x-ray film during exposure.

In radiography of thick parts, secondary radiation forms the greater percentage of radiation that would naturally pass to the film. As may be expected, any method of limiting the amount of this secondary radiation reaching the sensitized emulsion produces radiographic images of decidedly better quality.

It can, therefore, be seen that, with a knowledge of how kilovoltage affects the contrast of the image and secondary radiation, a balance of these factors, one against the other, leads to the selection of some fixed kilovoltage for each part of the body to be examined.

Grids The most effective way to cope with the problem of secondary radiation is through the use of a moving grid (Potter-Bucky diaphragm). This apparatus (Figure 14, page 28) consists of a grid which passes between the part and the film during exposure. The grid is composed of a series of strips of lead held in position by intervening strips of radiotransparent material, and is attached to a mechanism that moves it parallel to the plane of the film during exposure. The lead strips are tilted so that the plane of each is in line with the focal spot of the tube. The radiotransparent strips are usually about six times as deep as they are wide. The ratio of the height of the lead strips to the width of the intervening radiotransparent strips represents the grid ratio. The greater the ratio, the more efficient the grid is in re-

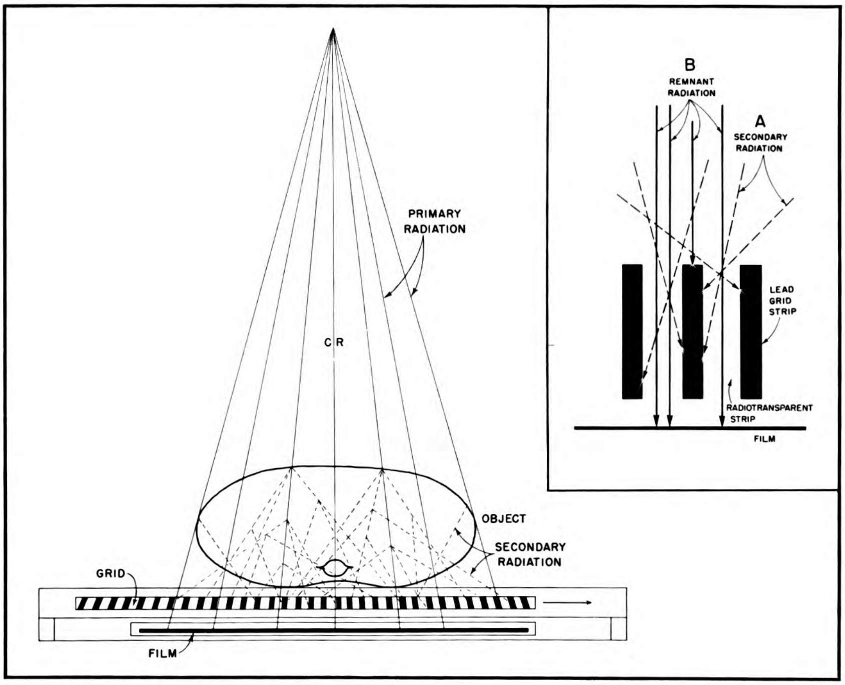


FIGURE 14—LEFT: Diagram of a Potter-Bucky diaphragm. **UPPER RIGHT:** Diagram of a small section of a grid, showing the manner in which secondary radiation **(A)** is absorbed and image-forming remnant radiation **(B)** passes through.

moving or absorbing secondary radiation. The strips of lead have the function of absorbing the diverse secondary rays that come from the part radiographed, so that the major portion of the image can be formed by the remnant radiation (see inset drawing, Figure 14).

For correct use of the grid, the focus-film distance must be 25 inches or more, dependent upon its design, and it must be so placed and centered that the primary x-ray beam will pass directly through the spaces between the lead strips. For stereoradiography, longitudinal tube shifts are permissible, but lateral shifts should not be extended more than 2 inches from the center of the grid.

The grid method of eliminating the major portion of secondary radiation naturally requires more radiographic exposure, and for that reason there is usually a need for employing intensifying screens to keep the time factor as short as possible. In addition, the device increases the distance between the part and the film, and thereby lessens sharpness to some extent. Hence, it is essential to use a tube with the smallest focal spot that will safely accommodate the exposures to be made, and a reasonably long focus-film distance. To meet these requirements, high-speed moving grids permitting exposures as short as 1/20 second have been developed. The same grid may also be used with longer exposures, up to ten seconds or more, so that it is applicable to practically all types of medical radiography. These grids are advantageous in radiography of the gastrointestinal tract, the gallbladder, and the genitourinary tract, as well as in the examination of large and pathologically dense chests that are not well visualized by routine methods.

Another type of grid, the stationary grid, is built of very thin, narrow strips of lead spaced closely together. It is placed between the patient and the film, without any accessories or driving mechanism. The grid casts distinct shadows of the lead strips on the film, which tend to break up minute detail in the radiographic image, but because of the fineness of its structure, the pattern is not seriously objectionable. While this grid is not as effective as the moving grid in removing secondary radiation, it is valuable in situations where the latter may not be available or applicable, as in bedside radiography or with the body positions that do not permit use of a moving grid. The stationary grid is also used, with desirable elimination of secondary radiation and improvement in quality, in photoradiography of the chest. The reduction in size of the image in photoradiographs renders the grid lines practically invisible.

If definite exposure factors have been established and it is desired to employ a grid, it is necessary to increase the time, milliamperage, or kilovoltage to compensate for the loss due to radiation absorption. This factor will vary considerably, however, with the thickness of the object being radiographed, as well as with the efficiency of the grid, for the more effective the grid in the removal of secondary radiation, the greater the increase required in exposure. This factor will vary considerably with the type and thickness of the part and must be established by trial.

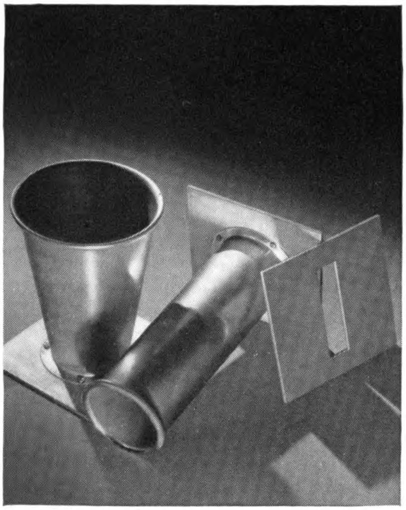


FIGURE 15—Cones and diaphragms commonly used in radiography for control of secondary radiation.

The final advantages of grid diaphragms in the majority of cases are that they permit inclusion of a large area of a thick part with a single exposure, and contribute to the contrast and absence of fog in the entire radiographic image.

Cones and Aperture Diaphragms

Prior to the introduction of grid diaphragms, cones of various shapes and sizes, and aperture diaphragms (Figure 15) consisting of sheets of lead with circular, rectangular, or square openings that restricted the area of exposure were the only means of *lessening* the effect of secondary radiation. When a cone or cut-out diaphragm is used, an increase in exposure of 25 to 50 per cent or more may be required, depending on the extent to which secondary radiation from a particular part has been reduced. In both instances, the percentage value must be determined with use of these accessories present in the laboratory.

The grid diaphragm does not always obviate the desirability of employing cones and cut-out diaphragms in most cases. When used in conjunction with a grid, these accessories restrict the area of exposure and thus lessen secondary radiation that is produced by x-rays striking the patient or sections of the apparatus lying outside the area of interest. If the circumstances under which the examination must be made are such that a grid is not usable, or not available, cones and aperture diaphragms are virtual necessities.

In stereoradiography, the employment of a cone or an aperture diaphragm requires the exercise of special precautions to ensure that in both exposures the x-ray beam is limited to the same area on the film. This may be accomplished by tilting the tube to compensate for the shift in tube position.

Anode "Heel Effect"

Various investigators have drawn attention to the angular distribution of radiation intensity from the anode face. Experiments have been described in which ionization measurements were made of the intensities emitted at various angles. The results were illuminating since a wide range of intensities that could have positive radiographic effect was demonstrated. Yet, little has been done to apply this inherent characteristic of all x-ray tubes — the "heel effect"— to influence balanced radiographic densities in the image. It must be understood that evidence of the "heel effect" does not signify a tube fault, for it is an advantageous characteristic of all x-ray tubes and is an invaluable means toward producing balanced radiographic densities.

The "heel effect" is a variation in x-ray intensity output (depending upon the angle of x-ray emission from the focal spot) along the longitudinal tube axis and in relation to the long axis of a film. The intensity diminishes fairly rapidly from the central ray toward the *anode* side of the x-ray beam; on the cathode side of the beam the intensity increases slightly over that of the central ray. Generally, the "heel effect" is limited in its application at long focus-film distances. Using average or short distances on large film areas, its effect is most advantageous particularly where decided differences in tissue densities require balancing of radiographic densities to avoid over- and underexposure within the same image.

The approximate percentage of x-ray intensity emitted by a tube at various angles of emission may be determined directly from photometric measurements of the radiographic blackening of an x-ray film. For radiographic purposes, this procedure is adequate and gives an indication of the approximate percentage of variation in the quantity that may

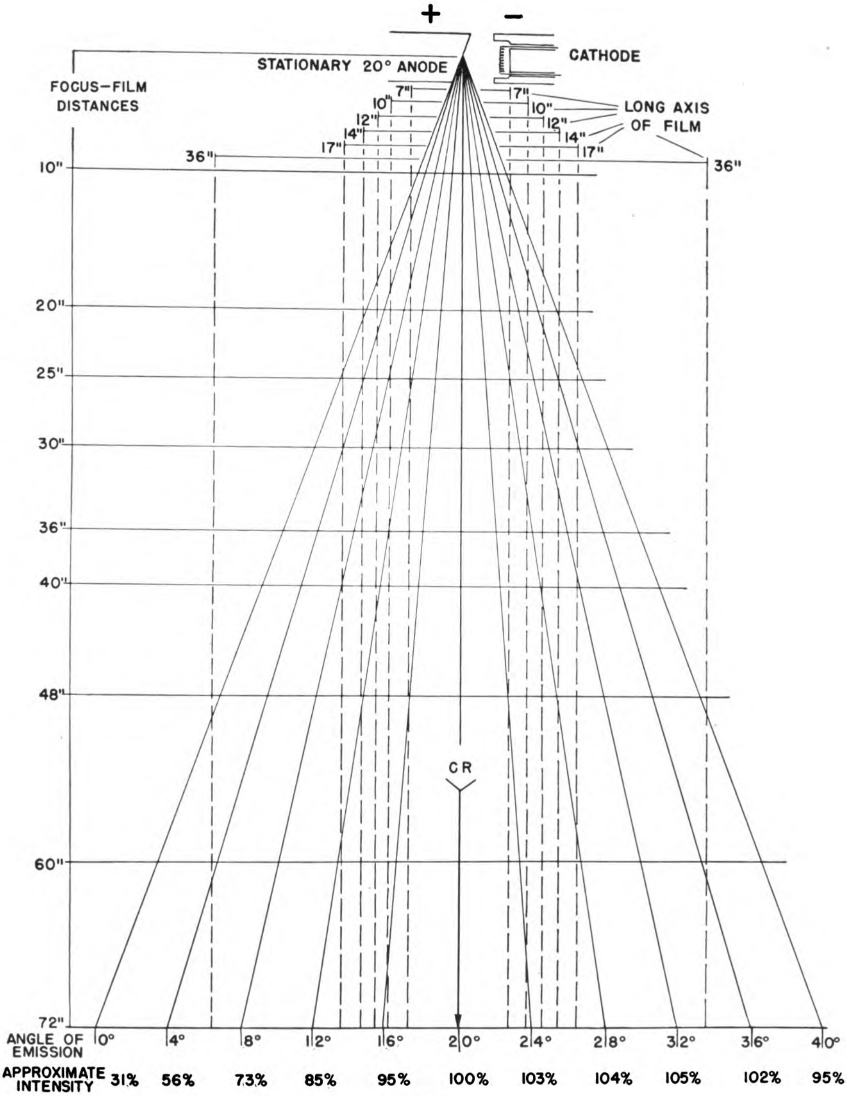


FIGURE 16

be expected when the x-ray beam falls on specific areas of different sizes of x-ray films at various focus-film distances. The diagram (Figure 16) graphically represents the mean values of radiographic density measurements obtained from many intensities emitted by various x-ray tubes. This diagram, drawn to scale, shows radii emanating from the target face, drawn at 4° intervals from 0° to 40° and intercepting horizontal lines representing various focus-film distances. At the termination of the radii at the bottom of the chart, the mean density values in percentages are indicated. For convenience, the radiographic density caused by the central ray (CR) is figured as 100 per cent. To the left, or anode side, of the central ray, the densities diminish in value, while those to the right, or cathode side, increase moderately and then decrease slightly.

The space between the vertical dotted lines beginning just below the diagram of the anode and terminating at the 72-inch focus-film distance line, when appropriately paired, indicates the length of each size of film and the approximate location at various focus-film distances of the respective density values created by the intensities of radiation at various angles of x-ray emission. For example, on the 48-inch focus-film distance line the outermost pair of vertical lines representing the 36-inch length of film passes outside the limits of the x-ray beam. In order to make use of the entire range of intensities on this length of film, it would be necessary to employ a focus-film distance of 49 inches. All intensity radii would intercept at this distance; consequently, if an exposure were made, the entire range of intensities would be expected to become evident on, let us say, a radiograph of an entire spine. Since the minimal intensity in the anode portion of the beam, approximately 31 per cent, is emitted in advance to the angle indicated at 0°, it is obvious that the portion of the spine having least tissue density (the neck) should be exposed by this portion of the beam and the heavier portion (the

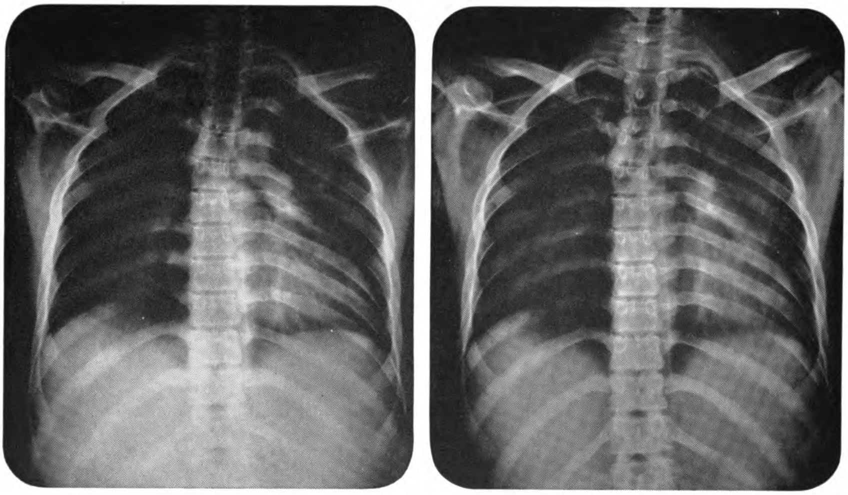


FIGURE 17—Anteroposterior radiographs of thoracic vertebrae that demonstrate the "heel" effect in radiography. **LEFT:** Cathode portion of the x-ray beam was directed cephalically; note overexposure of upper thoracic vertebrae and underexposure of lower thoracic vertebrae. **RIGHT:** Radiograph made with same factors but the cathode portion of the beam was directed caudally; note the balance obtained in the radiographic densities.

lumbar vertebrae), by the cathode portion of the beam.

When radiographs are made at relatively short focus-film distances, a knowledge of the distribution of the intensity in approximate percentages delivered to a particular size of film at a known focus-film distance is indispensable to correct alignment of the tube and part to the film at the most favorable focus-film distance. Radiographic densities cannot be balanced if only the intensity of the central ray is considered.

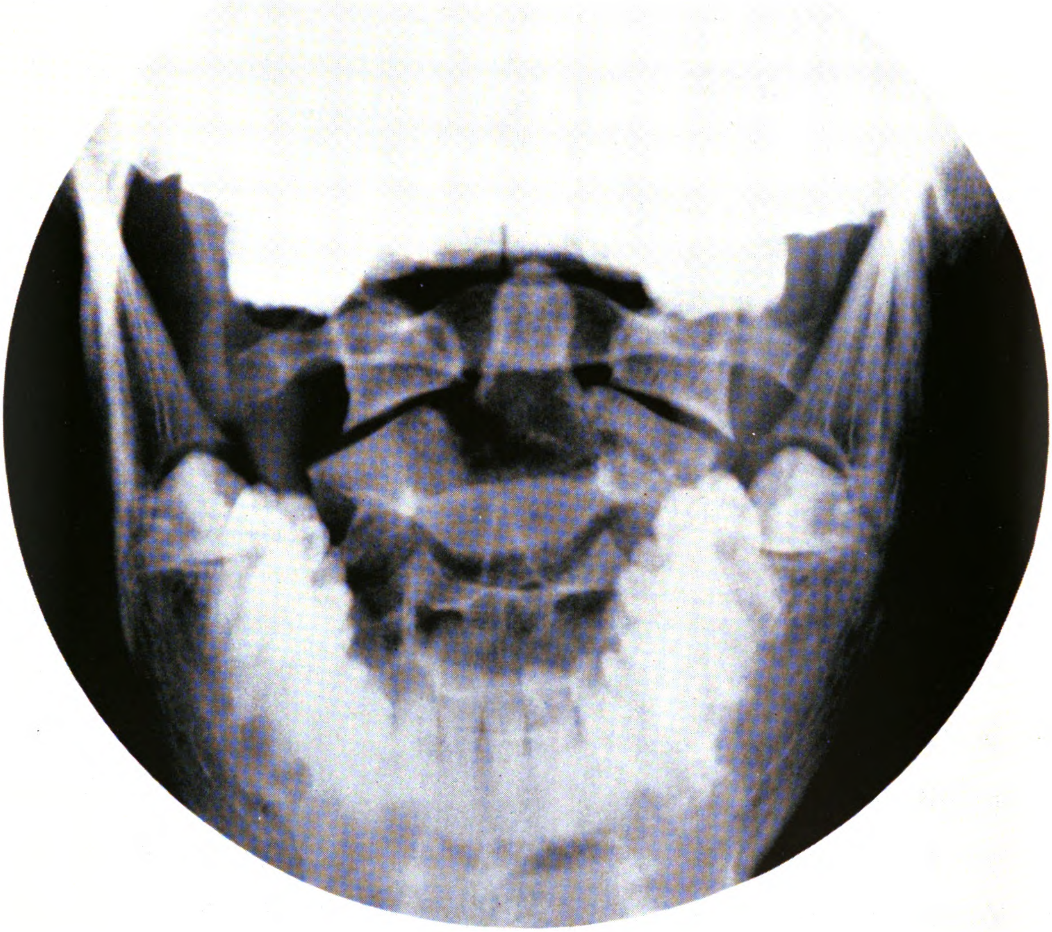
Radiographs are often secured in which a certain area of the image is definitely underexposed while another is overexposed, even though the factors seemed adequate for the tissue-density traversed by the central ray. This condition usually occurs when improper alignment of the tube relative to the part takes place. This lack of balance between radiographic densities is typical of the "heel effect" of the anode when it is improperly applied. An example is demonstrated by a radiograph of the thoracic vertebrae (Figure 17, left). By correctly applying the "heel effect," a radiograph (Figure 17, right) was obtained in which all densities were properly balanced.

The general rule for utilizing the "heel effect" is as follows: *Align the long axis of the tube parallel with the long axis of the part to be examined and direct the cathode portion of the beam toward the anatomic area of greatest tissue density.*

Summary

The following conditions are necessary if good-quality radiographs from the standpoint of density and contrast are to be secured:

1. The applied kilovoltage should be such that adequate penetration of the given part is obtained and optimum contrast produced.
2. The MAS value should be adequate to produce the necessary radiographic density.
3. Reduction of secondary radiation should be effected in all body parts by the use of a cone, grid, or aperture diaphragm.
4. Proper alignment of the tube to the part will assure balanced densities by virtue of correct application of the "heel effect."
5. The film must be processed as the manufacturer intended, otherwise the effort expended on making a satisfactory exposure will be lost; time-temperature processing is recommended and should be considered as a constant.



Radiograph of a dislocated cervical vertebra.

Geometry of X-ray Image Formation

• Since the radiographic image is a portrayal of the internal structures of an object placed in the path of an x-ray beam, its *formation* is dependent upon certain geometric conditions associated with its projection. Radiographic *detail* constitutes the recorded image, and *definition* is the term employed to describe the degree of sharpness with which the detail is recorded. Definition is influenced by the factors that enter into the geometric projection of the image. A number of these conditions are produced by light, so that by making use of that fact a convenient analogy can be made.

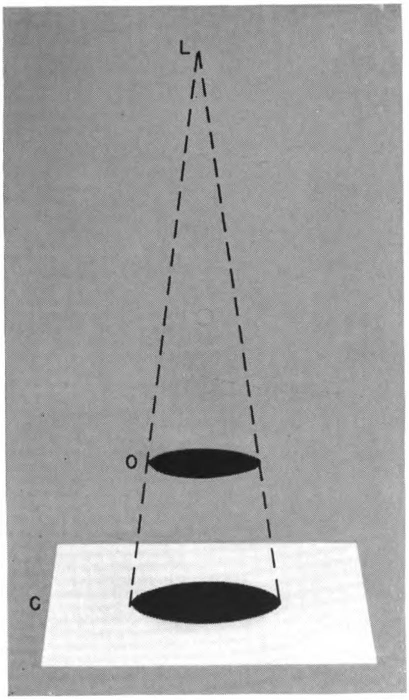


FIGURE 18

X-rays obey the common laws of light and, in general, image formation can be described in terms of light. Suppose, as in Figure 18, there is light from a point (L) falling on a white card (C), and an opaque object (O) is interposed between the light source and the card. A shadow of the object will be formed on the surface of the card.

This shadow naturally shows some *enlargement* because the object is not in contact with the card; the *degree of enlargement* will always vary according to the relative distances of the object from the card and from the light source. For example, if the object is moved nearer the card, a smaller shadow is produced. When the object remains at the same distance from the card while the distance from the light source to the card is increased, the size of the shadow is reduced. In each instance, the periphery of the shadow is demarcated sharply, because a point source of light was employed. The degree of sharpness of any shadow (or image) depends upon the size of the source of light and upon the po-

sition of the object between the light and the card—whether nearer to or farther from one or the other.

In Figure 19 conditions which are more comparable to those produced in radiography are shown. The source of light is a small area rather than a point. The relationship of object (O) and card (C) is the same as shown in Figure 18. Since many points of light emanate from L, many light beams strike the object, each casting a shadow on the card of its own making. The result is that the edge of the shadow appears diffused. In this case, also, the size of the shadow is greater than the object, but the periphery of the shadow is not sharp since it is diffused by the multiplicity of light rays emanating from the source. Some improvement in this condition may be secured if the light source remains the same but the object is placed nearer the card, thereby reducing the width of the penumbra. A comparable improvement in sharpness of the shadow also will occur when the light source is moved farther away from the object.

From the above it can be seen that the following apparent conditions must be fulfilled to produce a sharp shadow of an object:

1. The source of light should be small, i.e., as nearly a point source as can be obtained.
2. The source of light should be at as great a distance from the object as practicable.
3. The recording surface should be as close to the object as possible.
4. The light rays should be directed perpendicularly to the recording surface.
5. The plane of the object and the **plane of the recording surface should be parallel.**

The *form of the shadow* also may differ according to the angle which the object makes with the incident light rays. Deviation from the true shape of the object as exhibited in its shadow image is called *distortion.* For present purposes, however, the law governing the size of the shadow and the size of the object may be stated as follows:

The size of the shadow is to the size of the object as the distance of the light from the card is to the distance of the light from the object. The above conditions hold true in radiography.

When a radiographic image is projected from a small area, the borders

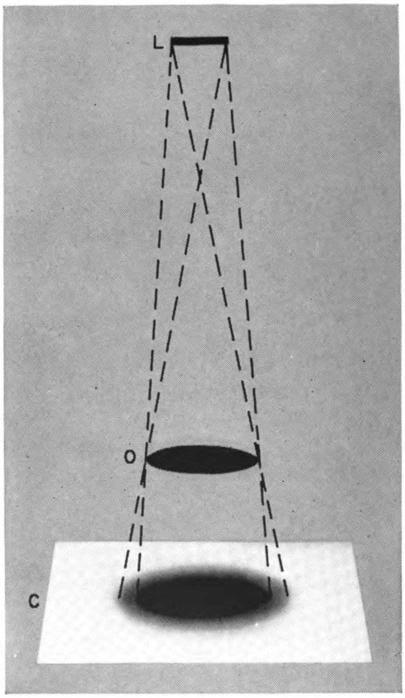


FIGURE 19

of the image are somewhat blurred (Figure 20, pages 38 and 39). The sharp edge of the image is known as the *umbra;* the diffused or unsharp periphery is called the *penumbra.* The size of the penumbra is determined by the size of the focal spot, the focus-film distance, and the object-film distance. When an image such as that produced in radiography is viewed, the image cannot ever be geometrically sharp because the recording surface consists of a large number of microscopic specks of silver and the object cannot in all its planes be ideally juxtaposed. The borders of the image, therefore, are really broken up into a number of microscopic specks which our eyes are not capable of seeing individually. The borders of the images, therefore, seem to consist of diffused lines of configuration and the degree of sharpness (or unsharpness) of the image can be recognized by the size of the penumbra.

Measures may be taken to reduce the penumbra to a minimum, so that visualization of the image is facilitated. This is accomplished by observing the following recommendations. The size and shape of the radiographic image of an object placed in the path of a beam of x-rays depend upon the distance between the object and the film—*object-film* distance—which should be as short as possible. The source of x-rays—the focal spot of the x-ray tube—should be as small as possible depending upon the choice of the current to be employed. The source of the x-rays also should be as far from the object as is practical—the focus-film distance. The x-ray film should be **placed as near the object as possible and its plane surface should be, as** often as necessary, perpendicular to the central ray arising from the focal spot. The planes of the object and film should be approximately parallel to avoid distortion.

The effects produced when various changes are made in the above factors are graphically illustrated in Figure 20. In A, an object (OB) was placed so that the object-film distance was long; a large focal spot (FS) was employed. The penumbra (P) as projected on the film was therefore wide, indicating excessive image unsharpness which was also influenced by the relatively short focus-film distance. This situation represents the worst sort of geometric relationship. In B, the same conditions prevailed as in A with the exception that a smaller focal spot was used. The narrower penumbra in B indicates that the unsharpness was less than in A.

In C, a long focus-film distance was employed with the other conditions remaining as in A. The increased focus-film distance narrowed the penumbra but not to the same extent as in B, where a smaller focal spot was employed. In D, the same conditions prevailed as in C with the exception that a small focal spot was used. The very narrow penumbra indicates a decrease in unsharpness due to the use of a smaller focal spot at a long focus-film distance. This condition should prevail when an appreciable object-film distance exists.

The diagram E indicates the object as being close to the film. An average focus-film distance and a large focal spot were used. Favorable

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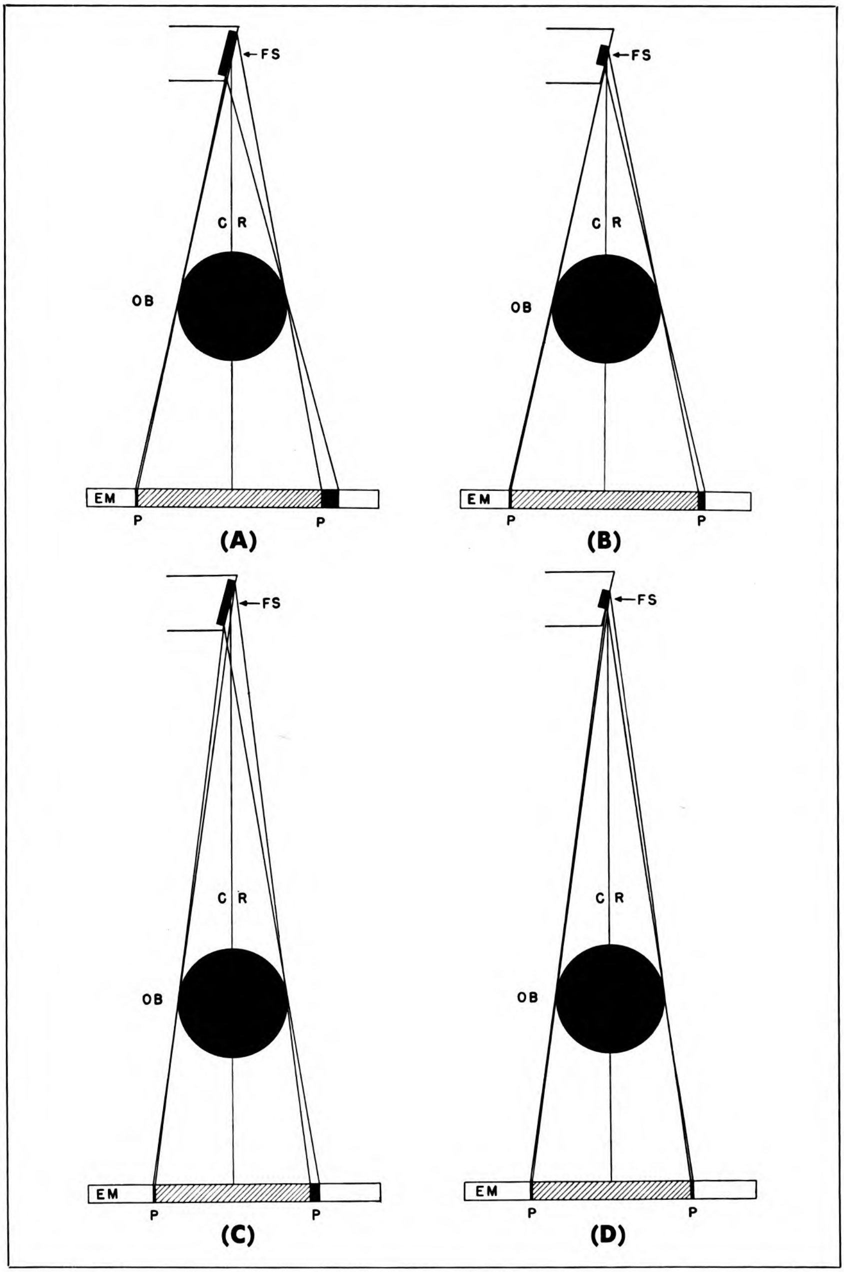
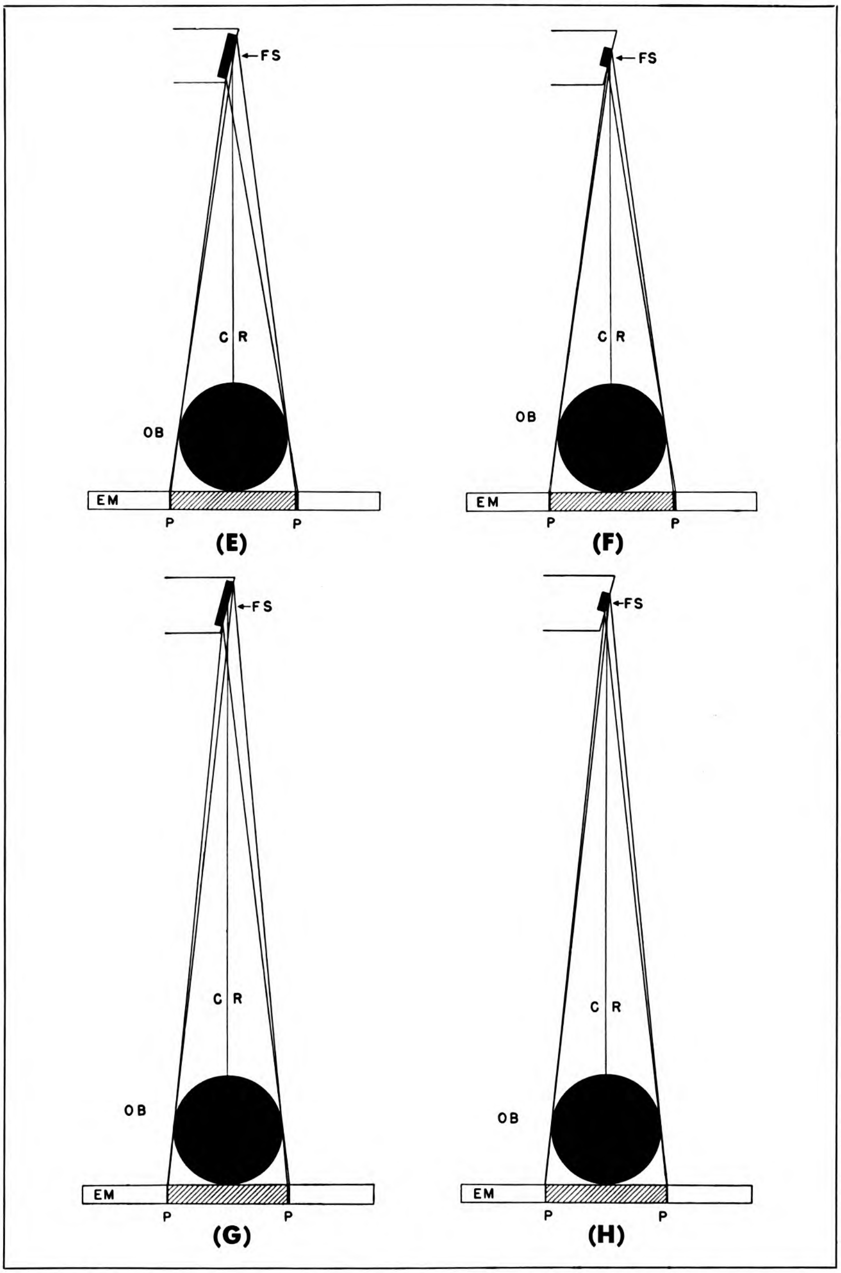


FIGURE 20—Diagrams showing the effect on image sharpness produced by variations in size of focal spot and object-film distance. Drawings A to D show degrees of unsharpness with



a long object-film distance; E to H show the improvement when the object is close to the film. **LEGEND:** FS—Focal spot; OB—Object; CR—Central ray; EM—Film emulsion; P—Penumbra.

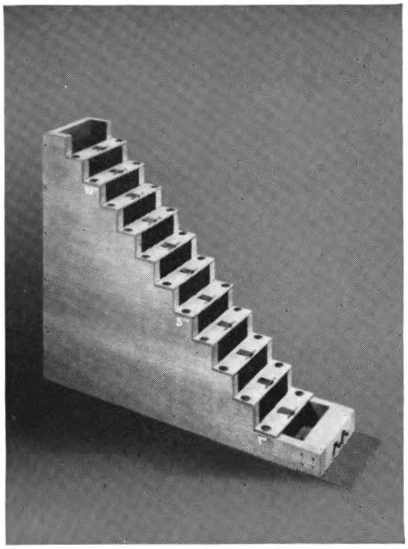


FIGURE 21—Wire meshes and metal bars arranged on a series of steps, for use in demonstration of effect resulting from change of object-film distance (see Figure 22).

sharpness was achieved, although a small focal spot, as shown in F, further improved the sharpness. In G, a large focal spot at a long focus-film distance with the object close to the film produced a very narrow penumbra. By employing a small focal spot under the same conditions as in G, maximum sharpness was obtained as shown in H, which may be considered ideal since unsharpness and magnification are minimal.

It will be noted that in A to D, despite the size of the focal spot and focus-film distance, the image or umbra is considerably magnified due to the object-film distance. In E to H, the umbra is only slightly magnified, due to the closeness of the object to the film. The ideal situation is shown in H where unsharpness and magnification are minimal.

Whether the focus-film distance is great or small, when an object-film distance exists, the image will *always* be magnified. The use of long focus-film distances in these situations serves to increase slightly the sharpness of definition and to decrease the size of the image. Therefore, it is advisable to place the film as close to the object as possible. (See Figures 21 and 22.)

A certain degree of magnification in the image is a normal occurrence. However, the focus- and object-film distance relationships influence its degree. When the object is close to the film, some magnification ensues because some portions of the object are farther than others from the film; the greatest magnification will, of course, be evident in the image of those structures that are the greatest distance from the recording film. Unequal magnification of the image cannot always be entirely eliminated either, but by the correct projection of the central ray it can be lessened to a point where it is not objectionable. (See Figure 23, page 42.) If the object is next to the film and in the path of the central ray, normal magnification of the image occurs. The central ray should not deviate too far from perpendicularity to the film if the proper geometric characteristics of the image are to be maintained.

A change in image sharpness occurs with respect to the projected focal spot. Maximum sharpness is obtained when small focal spots are employed. When a larger focal spot is used, some unsharpness occurs. A large-focus tube, although capable of withstanding very high energies, does not produce the sharpness of detail that is characteristic of tubes with fine focal spots, though relatively much lower energies are employed in the latter. In some instances, long focus-film distances will aid in showing sharper detail when employing a large-focus tube, but it is generally considered advantageous to use, whenever possible, the finer-focus tubes with smaller capacities or a rotating-anode tube.

When an object is placed next to the film, the unsharpness is minimal and its degree is directly attributable to the projected focal spot. When a short focus-film distance is employed, the unsharpness is increased. The image size of the parts of the object

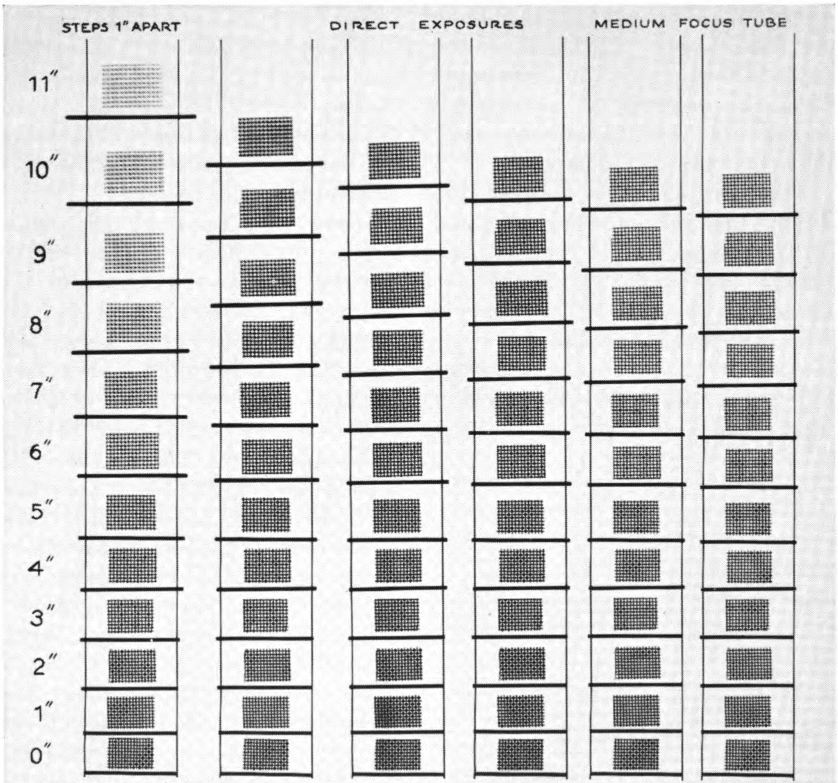


FIGURE 22—Radiograph of wire meshes and metal bars that were arranged on a series of steps (Figure 21) graphically demonstrates the various degrees of image sharpness and magnification that occur as a result of change in object-film distance as represented by each step. Note that sharpness and a minimum of magnification occur when the mesh and bar are near the film (0"); maximum unsharpness and magnification occur when object is placed at 11" from the film and exposed at a focus-film distance of 3'; maximum sharpness occurs when the object is placed on the film and a focus-film distance of 8' is used.

farthest from the plane of the film obviously becomes magnified.

The plane of that portion of the object or part nearest the film is always sharper than that plane farthest away; the detail is less sharply defined in the remaining object planes because the increasing remoteness of each plane from the film causes greater and greater unsharpness. The degree of unsharpness depends upon the size of the focal spot and the focus-film distance. At maximum focus-film distances, definition is improved and the image is more nearly the actual size of the part.

There are a number of other conditions that influence the definition in an image. When intensifying screens are employed, contact between the film and screens may be poor, which results in blurring of the image. Grids serve to increase the object-film distance with resulting diminution in image sharpness. Positioning and the degree of immobilization of the patient contribute greatly to the degree of sharpness with which the image is recorded.

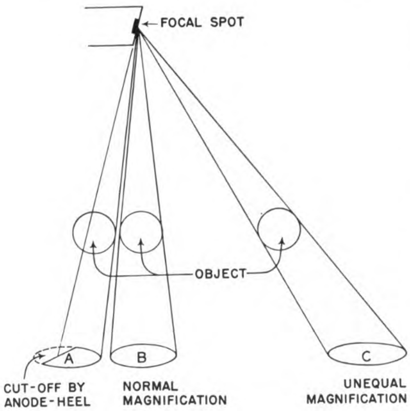


FIGURE 23—Diagram illustrating the geometric effect on the image when the position of the object is changed with respect to the focal spot; (A) image cutoff caused by "heel" of anode; (B and C) image enlarged.

Detail Visibility

In viewing a radiographic image, the eye can more readily differentiate between two areas of the image that are sharply demarcated rather than when their margins are diffused or blurred. Bone detail is more easily visualized if structural details are sharply defined (Figure 24). Good definition requires that unit densities be sharp and possess a contrast that makes the detail visible.

Detail may be rendered visible within the image by means of the contrast between the density of one component of the image and its neighbor. It may be due largely to a difference in brightness of a conspicuous detail within an area because the contrast between it and the surrounding area exceeds the minimum difference that the eye can perceive. In other words, the detail visibility consists entirely of differences in the opacity of the silver deposits in adjacent areas (contrast) which result in variations in the visual brightness of the tones.

Detail visibility is also dependent upon the sharpness with which the image is recorded. A happy combination of both contrast and sharpness provides the best detail visibility. Maximum visibility requires that the number of densities or tones be such that all essential details of the tissue or object radiographed be visible. Every portion of the image should possess visible detail; highlights (areas wholly or partially devoid of

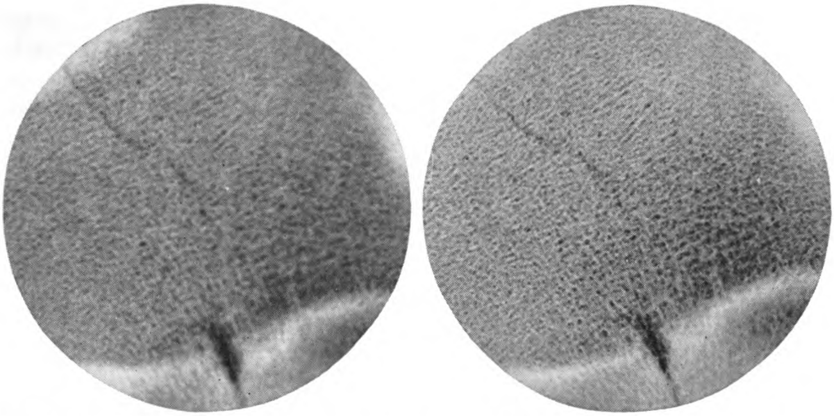


FIGURE 24—Radiographs of a section of dried bone. **LEFT:** Osseous detail is not easily visualized because of the unsharpness present. **RIGHT:** Detail is more readily visualized in this radiograph as compared to the one on the left because the bony structure is sharply defined.

detail) are objectionable. They should be avoided unless their presence is an acceptable characteristic of the tissue or object examined.

In rendering detail visible, contrast may be safely reduced, provided the maximum sharpness of detail is present. However, no scale of contrast can ever compensate for loss in detail sharpness except in those cases where the structural elements of a part comprise broad expanses of homogeneous tissue as in the gallbladder or renal areas.

When rendering detail in bony areas, small differential tones—long-scale contrast—should exist between the various structural elements. The scale of contrast can be greatly lengthened with excellent visualization of detail, provided the detail is sharply defined. In other words, when a small focal spot and a long focus-film distance and suitable screens are used to render the image sharply, the need for contrast is minimized, provided it is not less than required for proper visualization of the details within the structure being examined.

Detail visualization is markedly affected by secondary radiation fog; chemical fog due to the use of contaminated or aged solutions; or fog produced by rapid aging of the film under improper storage conditions, heat, humidity, or the fumes from volatile liquids or gases.

Radiography is not so exacting that it makes necessary the ultimate in the sharpness of the projected image, for even if it were attained, our eyes probably could not appreciate it; in fact, all desired information can be obtained from images possessing satisfactory contrast and sharpness of definition by which the eye can differentiate minute changes in structure.

Positioning

Posing the patient is facilitated by the use, whenever possible, of standard projections. Such projections secure radiographic images that reveal the maximum amount of diagnostic information with a minimum of distortion. An accurate idea of the anatomic arrangement of the internal structures with relation to some external or superficial anatomic landmark aids materially when posing the patient. A convenient method is to visualize the part as though it were transparent so that the usual structures which appear upon the radiograph may be identified in relation to the external landmark.

The relation of the central ray to the part to be radiographed, and to the film, must be carefully considered in each projection. Imperfect centering of the part on the film and alignment of the tube to the part are probably the most common sources of image distortion. It is advisable that the beginner purchase one or more good texts on radiographic technic.

The requirements of radiography are such that *slight* differences in position do not necessarily rule out the diagnostic value of the radiograph. A certain amount of latitude in routine posturing may be permissible, for the radiologist by reason of his experience and knowledge ordinarily can make satisfactory interpretations. However, in order to secure reliable diagnostic results, it is best to conform to a procedure which is precise and accurate, in addition to being standardized.

Immobilization

Complete immobilization is imperative in radiography, for differential diagnoses depend upon the visualization of sharp, undistorted images. In addition to careful posing of the patient and projection of the x-rays, movement should be practically eliminated during the exposure to avoid blurring of detail in the radiographic image. The responsibility of keeping immobile the part under examination should be that of the radiographer, not the patient, for movement may occur consciously or unconsciously. Respiration and muscle tremor are physical conditions that are important enough to warrant very close attention. To some patients, the mere fact that it is necessary for them to lie on a table for an x-ray examination is decidedly perturbing. Some may show signs of shivering or trembling. A few words of assurance that "everything will be all right" will help to restore peace of mind.

Even with the short exposures now possible, immobilization is necessary. There is no usable exposure so short as to fail to record minute uncontrollable or involuntary tremors of the area under examination. Proper immobilization also assures a comparison of symmetrical parts, for it serves to prevent involuntary rotation of the part.

Too much should not be left to the patient in the matter of keeping still during the exposure. Most patients are not familiar with the requirements of making a radiograph. Frequently, they are somewhat nervous and perhaps even afraid, so it is the job of the radiographer to make the patient at ease—so that he is comfortable, mentally and physically.

When the radiographer has posed the patient with a minimum of discomfort and has allayed any trepidation, much has been done toward securing his cooperation. However, the radiographer's task does not end there, as much of his success is dependent upon the closeness and firmness with which the part is juxtaposed to the film holder and the kind of immobilization obtained. The tube carriage always should be locked in position to prevent vibration.

There are a number of methods for immobilizing the part: sandbags, compression bands, and special clamps, all have their place. Compression bands should be clean and of washable material. If *double* compression cranks are employed, rotation of the part is largely avoided, as a simultaneous equal pull from both sides is obtained. Most Potter-Bucky diaphragms and x-ray tables are equipped with these devices.

Making the Radiograph

The making of a good-quality radiograph is dependent not only upon the choice of optimum exposure factors but also upon the manner in which the projection is made. Precise positioning of the patient with proper relation to the central ray provides neat, orderly radiographic images that are more easily read by the radiologist. Such images avoid the necessity for excessive handling of the radiographs during interpretation.

For example, when an anteroposterior radiograph of the odontoid process of the second cervical vertebra is desired, the patient should be posed in relation to the central ray and the film as shown in Figure 25. The resulting radiograph (Figure 26) shows the odontoid process projected through the foramen magnum.

It is also important to observe that routine projections of various portions of the body require that certain combinations of factors and accessories always be employed. These combinations are: (1) exposures requiring the use only of plain film in exposure holders; (2) those which employ screens; and (3) those requiring screens and a grid, either stationary or moving.

In radiography it is necessary to exhibit abnormal conditions with at least two views of the area of interest

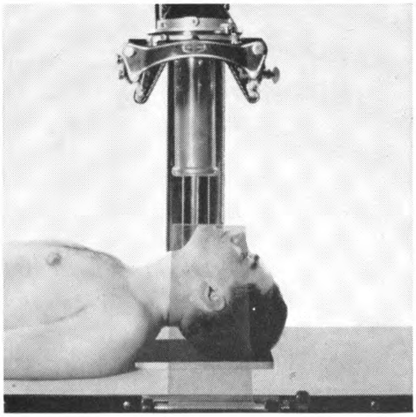


FIGURE 25

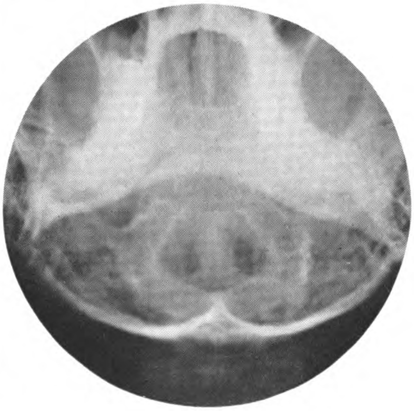


FIGURE 26

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Projections from different directions serve to orient the radiologist more intelligently concerning a situation, particularly in fracture or foreign-body cases.

In summary, the production of a radiograph is not only dependent upon all those factors described in the chapter, "Recording the Image," but also on those that concern the geometry of the formation of the image. The latter are as follows:

1. A small focal spot which is in conformity with the MAS employed should be used.
2. The focus-film distance should be as long as conditions will allow.
3. The object-film distance should be at a minimum.
4. The x-ray beam should be directed perpendicularly to the plane of the film whenever possible; the central portion of the x-ray beam (central ray) should be directed to the center of the object.
5. Intensifying screens, if used, should make good contact with the film.
6. The patient should be posed properly.
7. Movement of patient or tube should be eliminated or minimized.

Intensifying Screens

• When an x-ray beam strikes an x-ray film, less than 1 per cent of the radiant energy is absorbed by the emulsion, and, as a result, more than 99 per cent fails to perform any useful radiographic work. Since the absorption of the rays by the emulsion primarily governs the formation of the *latent image*, it is obvious that in many situations a means of more fully utilizing their energy, without complicating the technical procedure, is highly desirable. The function of intensifying screens is to increase the effect of the x-radiation on the sensitized emulsion by means of fluorescence, and thus reduce the exposure time.

Certain chemicals have the ability to absorb x-rays and instantaneously emit light. This property is called *fluorescence.* The compound that is most commonly employed in intensifying screens is the white crystalline salt, calcium tungstate, because of its effectiveness as a fluorescent agent and its general advantages in manufacture and use. It is finely powdered, mixed with a suitable binder, and coated in a thin, smooth layer on a special cardboard support.

When intensifying screens are employed, the film is placed between the active faces of the two screens which absorb considerable x-ray energy and fluoresce. Films that are manufactured for use with intensifying screens are especially sensitive to blue-violet light and hence to the fluorescent light of the screens. When the film is exposed to x-rays, it receives not only an x-ray exposure but also a photographic one from the fluorescent light of both screens. This combined action serves to produce the required radiographic density. In this way, almost the entire effect of the x-radiation on the film is caused by the fluorescent light of the screens, and relatively short exposures become practicable, although at the expense of some sacrifice of sharpness of definition. This loss in sharpness is caused principally by the diffusion of fluorescent light across image boundaries within the body of the screen itself.

The three types of screens most widely employed in radiography are the "high-definition," the "average-speed" and "speed." The "high-definition" type is used where sharpness of definition is of first importance at some expense in exposure time. The "average-speed" screens are valuable where good definition is obtained with shorter exposure. The "speed" screens are designed for situations wherein shortness of exposure is of prime importance.

The size of the calcium tungstate crystals in a screen largely deter-

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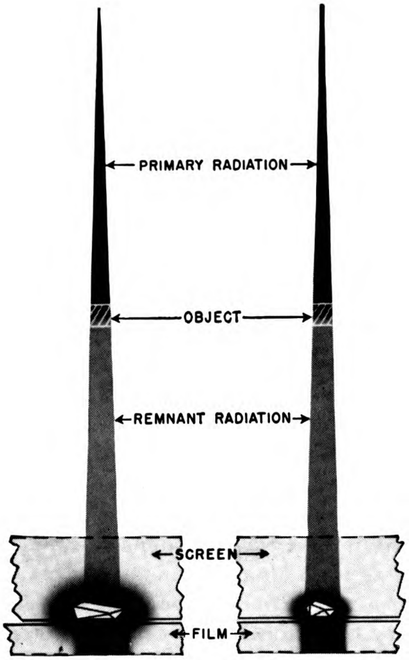

FIGURE 27—Diagram illustrating effect of size of calcium tungstate crystals on image sharpness. **LEFT:** Large crystal, which creates image unsharpness. **RIGHT:** Small crystal, which contributes to image sharpness.

mines its speed and the sharpness of definition. Relatively *large* crystals are used for fast screens. With their use, some sharpness of detail is sacrificed to effect a gain in speed. Relatively *small* crystals are employed in the high-definition screens to attain maximum sharpness of definition; this is obtained, however, at some loss in speed (Figure 27). The fine-grain screen, possessing slightly larger crystals, provides an image with satisfactory speed and sharpness of definition. When the higher kilovoltages are employed, the high-definition or fine-grain screens provide excellent detail sharpness, and the exposure times are well within the range of capabilities of most x-ray apparatus.

Kodak Contact X-ray Screens are manufactured in the three types defined above. High-Definition Screens are of the first type. Fine-Grain Screens are of the second type, and with average kilovoltages require 4 KvP less than the first type. Ultra-Speed Screens are of the third type and provide the maximum practical speed that modern screens possess. Their speed with average kilovoltages is 4 KvP less than that required by Fine-Grain Screens; the difference in image unsharpness is minimal.

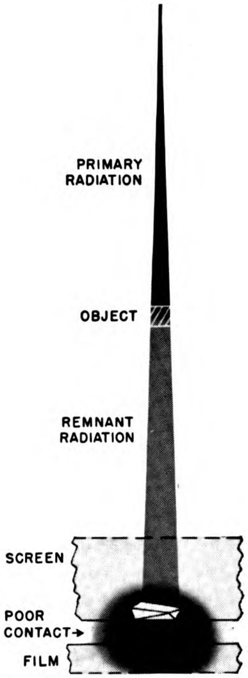

FIGURE 28—Diagram illustrating creeping of fluorescent light into the space between film and screens when contact is poor. Note how the detail is diffused or unsharp.

Screens-Film Contact Close contact between the active surfaces of the screens and the emulsion surfaces of the film is essential so that sharpness of detail will not be impaired. Poor or uneven contact allows the fluorescent light to spread and produce unsharpness in the image. (See Figure 28.) For that reason, each pair of screens is mounted in a rigid cassette. Theoretically, the pressure applied by the springs on the back of the cassette produces equal contact between screens and film. Actually, however, with use, cassettes in time become somewhat deformed so that close screens-film apposition is lost. To compensate this deficiency, Kodak Contact X-ray Screens are so designed that a small volume of air is hermetically sealed in a thin plastic container that is affixed to the back of each screen. The entrapped air exerts equal pressure on the screen and film wherever inequalities in contact occur, thereby maintaining equal screens-film contact over the effective screen area. This pneumatic cushion is an integral part of Kodak Contact X-ray Screens. A diagrammatic representation of the screens-film contact effected with these screens is shown in Figure 29.

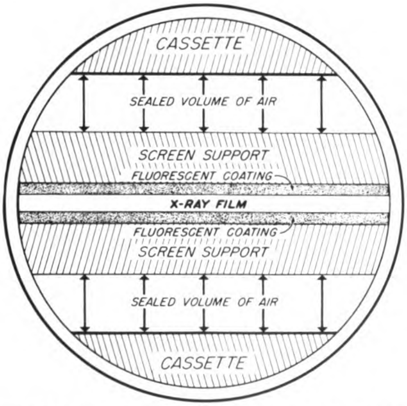

FIGURE 29—Schematic cross section of cassette-screens-film "sandwich" showing the action of the pneumatic cushion in equalizing pressure on the film and screens.

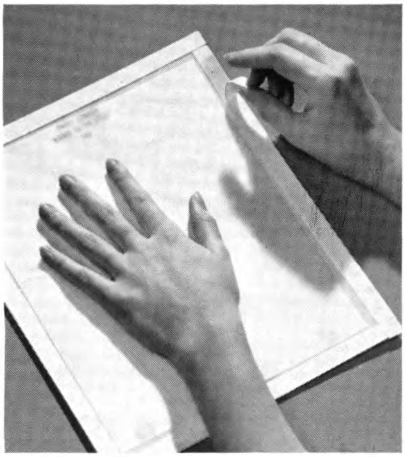

FIGURE 30—Removing paper scrim from edge of Kodak Contact X-ray Screen preparatory to mounting it in a cassette.

Mounting Screens Special double-faced adhesive tape is affixed to the back of Kodak Contact X-ray Screens so that, after the paper scrim is removed (Figure 30), they may be mounted in the cassette. The screens are carefully placed in the cassette and the cassette springs closed. It is not only important that good adhesion be obtained but that the pneumatic cushion provide the necessary uniform screens-film contact. After the screens are mounted, the cassette should remain closed overnight so that the pneumatic cushion will be thoroughly adjusted to the cassette while under pressure. The screens may be used the next day.

Screens may be removed easily at any time by carefully lifting apart

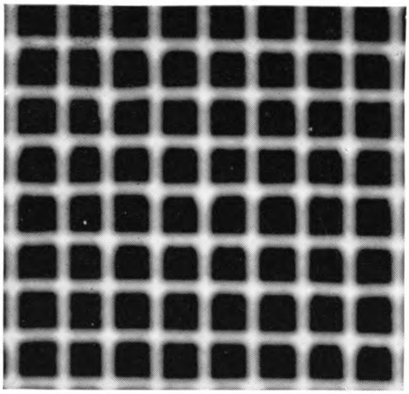

FIGURE 31—Poor screens-film contact results in a fuzzy image.

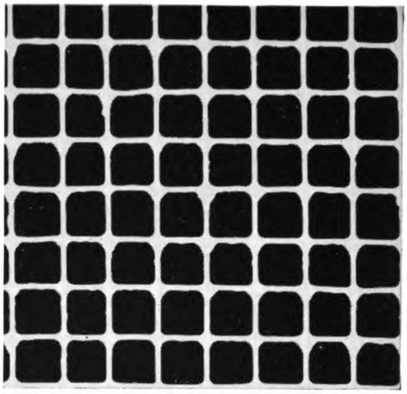

FIGURE 32—Good screens-film contact helps to provide a sharp image.

the adhered areas with a broad, dull knife blade. Before mounting new screens, old cassettes should be cleaned carefully to remove any adhesive used previously. This is necessary to eliminate the chance for imperfect screen contact and to assure good adhesion of the new screens.

Test for Screen Contact Cassettes must always be handled carefully so they do not become dented or otherwise damaged and thus cause faulty contact between the screens and film. As a matter of routine, all cassettes should be tested periodically to check on the contact they provide. This may be easily done by securing a 14x17-inch piece of wire screening (either 1/16- or 1/2-inch mesh is satisfactory) and framing it so it will lie flat. The cassette is then loaded with a film, the wire placed on the exposure side of the cassette, and a flash exposure made. If there are areas of inadequate contact, the result will be as shown in Figure 31, wherein the open space between the film and the screens permits extension of fluorescent light to neighboring areas and causes unsharpness of the detail in the area of poor contact. If there is proper contact, the radiographic image of the wire will be sharp as shown in Figure 32. A method that may be used for correction of poor screen contact with screens not equipped with pneumatic cushions is to build up the *back* screen with paper — the paper folded around Kodak x-ray film in packing is suitable for this purpose. A series of oval pieces, each slightly smaller in area, is cut out of paper and tipped together with *minute* daubs of glue or paste. The "pack" thus formed (Figure 33) is then tipped to the felt padding of the cassette cover, under the *back* screen.

Care of Screens and Cassettes As screens influence the quality of the radiograph, their proper care is important. They should be clean, free from marks, stains, and opaque matter, and should be examined frequently for foreign material such as metal particles or dirt embedded in the surface, developer stains, scratches, or cracks. As soon as screens appear de-

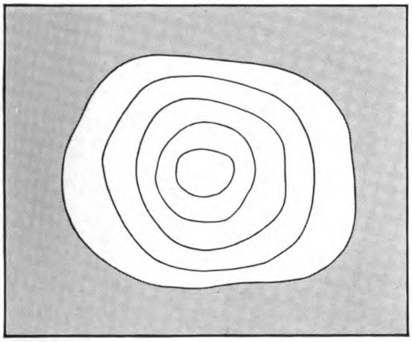

FIGURE 33—Representation of paper "pack" that would re-establish contact in area indicated in Figure 31.

fective, they should be replaced with new ones.

Because the fluorescent light emitted by intensifying screens obeys the laws of light, any foreign matter on a screen will absorb light during the exposure and cause objectionable marks in the radiograph. Consequently, bits of paper, lint, and dust should be carefully removed, and dirt and stains should never be allowed to remain on the surfaces of the screens. To guard against finger marks, the active surfaces should not be touched or handled except in washing. And, of course, care must be taken to avoid scratching them.

The surfaces of Kodak Contact X-ray Screens are given a special coating to protect them from abrasion and wear. This coating, being waterproof and applied on both sides, prevents the absorption of moisture. If markings are accidentally acquired, the active surface of the screen may be cleaned by careful application of a mild white soap and water, using a soft cloth or cotton and a minimum of water. After cleaning, the screens should be wiped clean of soap with clear water and allowed to dry. To remove exceptionally greasy deposits, a cotton tuft moistened with white gasoline or benzene should first be used and the screens then washed as described above. The use of solvents such as methyl alcohol should be avoided as they may damage the active surface.

Hydrogen peroxide or common cleaning fluids should never be used on intensifying screens, because their chemical composition is such that fogging of the film emulsion is almost certain to result. Placing thin cellulose acetate sheets over the active surfaces as a protection also is objectionable. When such a protector is used, merely opening the cassette will, under certain atmospheric conditions, cause a static electric discharge between the protective sheets and the film that will produce artifacts in the radiograph.

Cassettes may be stored in the processing room, but they should be kept at a safe distance from chemicals and all other possible sources of contamination or damage. Developer stains cannot be removed from screens. Cassettes should always be handled on the "dry side" of the processing room so that solutions will not be splashed on them. They should be kept closed when not in use.

X-ray Film

• X-ray film is composed of an x-radiation sensitive emulsion—gelatin suspension of tiny crystals of silver bromide — and a blue-tinted, transparent, cellulose acetate support or base. The emulsion is coated on both sides of the base in layers about .001 inch thick. The base furnishes support for the emulsion and provides the correct degree of stiffness for handling purposes. Since x-radiation passes readily through film—and intensifying screens when used—the x-rays expose the emulsion on both sides of the film, thereby producing a greater photographic effect than is possible with a single emulsion.

The crystals of silver bromide in the emulsion require considerable magnification to be visible. When affected by x-rays, a minute part of the crystal separates into the silver and bromide ions of which it is composed. It is these affected crystals which contain the *latent* image. The latent image obviously cannot be seen or detected by any physical means, but it can be made visible by subjecting the film to a chemical treatment known as *development.* Upon development, the affected crystals are changed into black metallic silver by the x-ray developer's action. Thus, the developer completes the process begun by exposure to the x-rays.

The finely dispersed metallic silver appears black, and the different degrees of blackening depend upon the *intensity* of the x-radiation reaching the film and duration of exposure. The varying degrees of concentration of silver are known as *radiographic densities,* which normally constitute the radiographic image. The crystals which are *not* affected by the x-rays or developer are removed by treatment with another solution known as the fixer. This bath has no effect on the black metallic silver comprising the image, unless the film is left in the bath for a prolonged period of time.

Types In radiography it is necessary to employ a film that is capable of recording, with sufficient contrast, slight variations in x-ray absorption in the part x-rayed and to show these differences over a wide range of radiographic densities in the same exposure. In other words, an x-ray film must be able to provide adequate contrast and at the same time show fine tonal gradation and detail in the developed image. Uniformity and adequate film exposure latitude to offset errors in exposure are further essentials. All these qualities are scientifically maintained in all Kodak x-ray films.

While an image may be formed by light, gamma rays, and other forms of radiation, as well as by x-rays, the

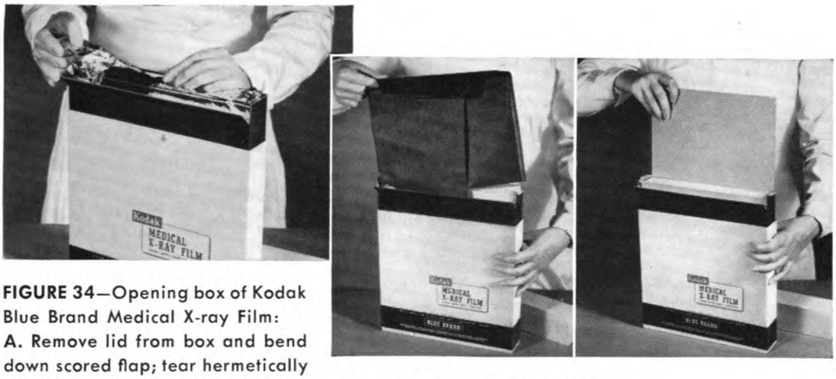

FIGURE 34—Opening box of Kodak Blue Brand Medical X-ray Film:
A. Remove lid from box and bend down scored flap; tear hermetically sealed foil wrapping at center and strip toward side of box; repeat for other half.
B. Pull off black paper cap.
C. Withdraw both cardboard stiffeners to permit easy removal of the first few sheets of film.

properties of the latter are of a distinct character, and for this reason x-ray film must be radically different from that used in photography. Two types of x-ray film are now employed in medical radiography: (1) *screen-exposure* film, which is especially sensitive to the fluorescent light of intensifying screens and not so sensitive to the direct action of x-rays; (2) *direct-exposure* film, which is highly sensitive to the direct action of x-rays and should not be employed with screens. When used with intensifying screens, screen-exposure film is much faster than the direct-exposure or no-screen type. When screen-exposure film is used without intensifying screens, however, it is slower than the direct-exposure type.

Kodak x-ray film for medical purposes is manufactured in the above-mentioned types: (1) The *screen-exposure* film is the well-known Kodak Blue Brand Medical X-ray Film, an extremely fast film with wide exposure latitude designed especially for use with intensifying screens. (2) The *direct-exposure* film is Kodak No-Screen Medical X-ray Film, possessing maximum sensitivity to direct x-radiation, and intended for use without screens. Its increased speed for direct exposures and its latitude and superior contrast make it of value for numerous applications.

Photography of the x-ray image on a fluorescent screen — photoradiography — requires the use of either of two types of single-coated film. The four Kodak films made for this purpose are described on page 104, in the section on "photoradiography."

For dental radiography* there are available a variety of films and three types of packet in which the film is enclosed — for periapical, interproximal, and occlusal radiography.

Film Packaging To ensure that the user of Kodak x-ray film receives it in the best possible condition, packaging is a rigidly controlled procedure. As a result of extensive experimentation under tropical, temperate, and artic conditions, Kodak has evolved a packaging method that

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*The publication, *X-rays in Dentistry*, free upon request to the *Medical Division*, is a text which describes dental film and its numerous applications in dental practice.

permits longer life of x-ray film wherever it may be used. Kodak x-ray film is enclosed in a hermetically sealed metal foil inner wrapper (Figure 34, page 53) that assures unequaled protection against moisture. As long as the foil wrapper is unbroken, moisture vapor cannot get in or out — the film holds its initial moisture-balance indefinitely.

Interleaving the sheets of film with specially prepared paper and wrapping them between various layers of cardboard and moistureproof paper are further protective measures. When packed for *export* shipment, special moistureproof outer wrappings are also used so that the deleterious effects of over-water shipment are avoided. In other words, every effort is made to ensure the user of Kodak x-ray film a good-quality product upon its arrival anywhere in the world.

Another requisite of a good package is ease of opening, and Kodak has given due consideration to this problem also. The illustrations shown as Figure 34 demonstrate how easy it is to open a box of Blue Brand Film. After the outer box top is removed, the side of the cardboard box is partially folded down to the creased line (about 1 inch from the top) and the hermetically sealed foil wrapping is grasped in the center of the folded lip and torn as one would a piece of paper. Then, the foil is torn away from the top of the package, working outward from the center. Next, the cap portion of the inner black paper wrapper is pulled off. The cardboard stiffener is then withdrawn to facilitate removal of films in individual paper folders.

Storage of Film It must be appreciated that x-ray film is a delicate material, and it cannot be handled carelessly or roughly. It is very sensitive to treatment of any kind, and heat, light, x-rays, radium, chemical fumes, pressure, rolling, bending, and so forth, are capable of adversely affecting the emulsion. Consequently, care must always be exercised in its manipulation and storage. Film should always be kept in a cool, dry place and bought in such quantities that the supply is renewed frequently. In extremely warm climates only small quantities should be ordered so that a rapid turnover of film takes place.

Film must be suitably protected from the unwanted action of x-rays or radium by lead-lined walls or chests. Film bins in the processing room must also be protected by sheet lead. The table on page 55 indicates the distances from the source of radiation, the varying amounts of radium at the source, and the thicknesses of lead surrounding the radium, which will produce a slight degree of fog on Blue Brand X-ray Film (stored for three weeks) and No-Screen X-ray Film (stored for four weeks). The lead protection and distances should be considered as minimum conditions tolerable. Other x-ray films may be stored under the same conditions as Blue Brand Film.

X-ray film must never be stored in drug rooms or other places containing fumes of any kind. Illuminating gas, formalin, ammonia, volatile oils, or sewer gas will surely fog film if it is stored in an atmosphere containing any of these substances.

Film should never be subjected to

Minimum Protective Conditions for Film

Distance from Radiation Source (in feet)	Amount of Radium (in milligrams)									
	25	*50*	*75*	*100*	*150*	*200*	*300*	*400*	*500*	*600*
	Lead Surrounding Radium (in inches)									
25	2.5	3.0	3.0	3.5	3.5	4.0	4.0	4.5	4.5	4.5
50	1.5	2.0	2.0	2.5	2.5	3.0	3.0	3.5	3.5	3.5
100	0.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	2.5	2.5
200				0.5	0.5	1.0	1.0	1.5	1.5	1.5
400								0.5	0.5	0.5

extreme pressure, such as in wrinkling, bending, or rolling, because changes take place in the emulsion which, upon development, appear as artifacts on the finished film. An artifact is a mark foreign to the image which is not imposed on the film by the action of x-rays. To avoid such pressure markings, packages of unexposed film should be stored *on edge;* they should never be stacked upon one another.

Any form of white light creeping into a processing room through cracks around the edges of partitions or doors may fog a film. Only that light from a properly constructed safelight lamp containing a lamp of the proper wattage, and equipped with a Kodak Safelight Filter, Wratten Series 6B, should be permitted to fall on the film during its handling. But even this light may fog film if permitted to shine on a particular area for too long an interval. No film should be exposed to the safelight lamp for a period longer than it takes to unload a film, place it in its hanger, and immerse it in the developing solution. This time is usually estimated as one minute.

Kodak x-ray films present no greater hazard in the stock, radiographic, processing, or filing rooms than would an equal quantity of paper records. Radiographs made with them can be stored on open shelves, in manila envelopes. Discarded film boxes may be stood on edge and employed for filing purposes, providing an orderly arrangement.

Manipulation

X-ray film is a sensitive and easily damaged material and it must be handled carefully if the best radiographic results are to be obtained. Film should not be subjected to physical strains, such as pressure, creasing, buckling, or folding. In taking the film from the carton, one should always remove the film with its folded paper wrapper; rapid movement should be avoided as a protection against static. Then the film should be held vertically at the middle of the top with the finger tips of the right hand while the edges of the wrapper are opened. The paper leaves can then be carefully separated from the film, which is regrasped by the finger tips of the right hand, and permitted to fall away from the film into the left hand. Af-

ter disposal of the paper, the lower edge of the freely suspended film is grasped by the finger tips of the left hand, and the film placed in the cassette. The paper should not be removed, however, if the film is to be used in exposure holders instead of cassettes. Dental films should be held at the edges after the packet wrappings have been removed. Such care will prevent many types of marks from appearing on the film.

Every precaution is used in the manufacture and packing of Kodak x-ray film to avoid the accumulation of static electricity on the film. During the emulsion-coating operation, electricity is removed by ingenious and complicated methods so that static charges have no opportunity to accumulate on the film and lead to static marks on the finished radiograph. The fact that the film is coated and dried in an atmosphere free of dust and at optimum and constant temperature and humidity serves to keep the formation and production of static electricity at a minimum.

A static electric discharge emits light capable of sensitizing the film. Static marks assume various shapes. They are usually treelike or bushlike, and the point of discharge always has the greatest density with branching processes emanating outward from this point. Static discharges are most likely to occur in cold, dry periods (winter), and it is then that particular care must be taken to handle film carefully and avoid friction on its surface. The loading bench may be grounded so that in handling the cassette any static charges that are built up can be dissipated before the cassette is opened.

Loading Film

There are two types of containers in which x-ray films can be held during exposure — cassettes and cardboard exposure holders. The choice depends upon the situation. In the double-intensifying-screen technic, the film is placed between two x-ray intensifying screens which are mounted in a cassette. In the direct-exposure procedure, the film is placed in an exposure holder comprising a lighttight envelope mounted between two pieces of paperboard hinged together.

When loading a cassette, the film *without the paper* is placed in the bottom of the cassette and superimposed on the front intensifying screen. The lid carrying the other screen is gently closed and locked by means of the back springs. When placing the film in the cassette, care should be exercised to avoid scraping or sliding the film over the edges of the cassette or surface of the screen. (See Figure 35.)

Kodak X-ray Film Exposure Holders are made especially for direct-exposure. The two pieces of radiotransparent paperboard that comprise the covers are held together with heavy binding cloth. To one cover, a metal clip is attached on a pivot; laminated to the inside of the cover is thin lead foil that protects the film from secondary radiation arising from the table top. Affixed to the inside of the other cover is an envelope that folds around the film and excludes all light. In loading the holder, the film *with the paper around it* is placed in the open holder; next, the large flap of the envelope is turned down, then the side flaps are brought over, followed by

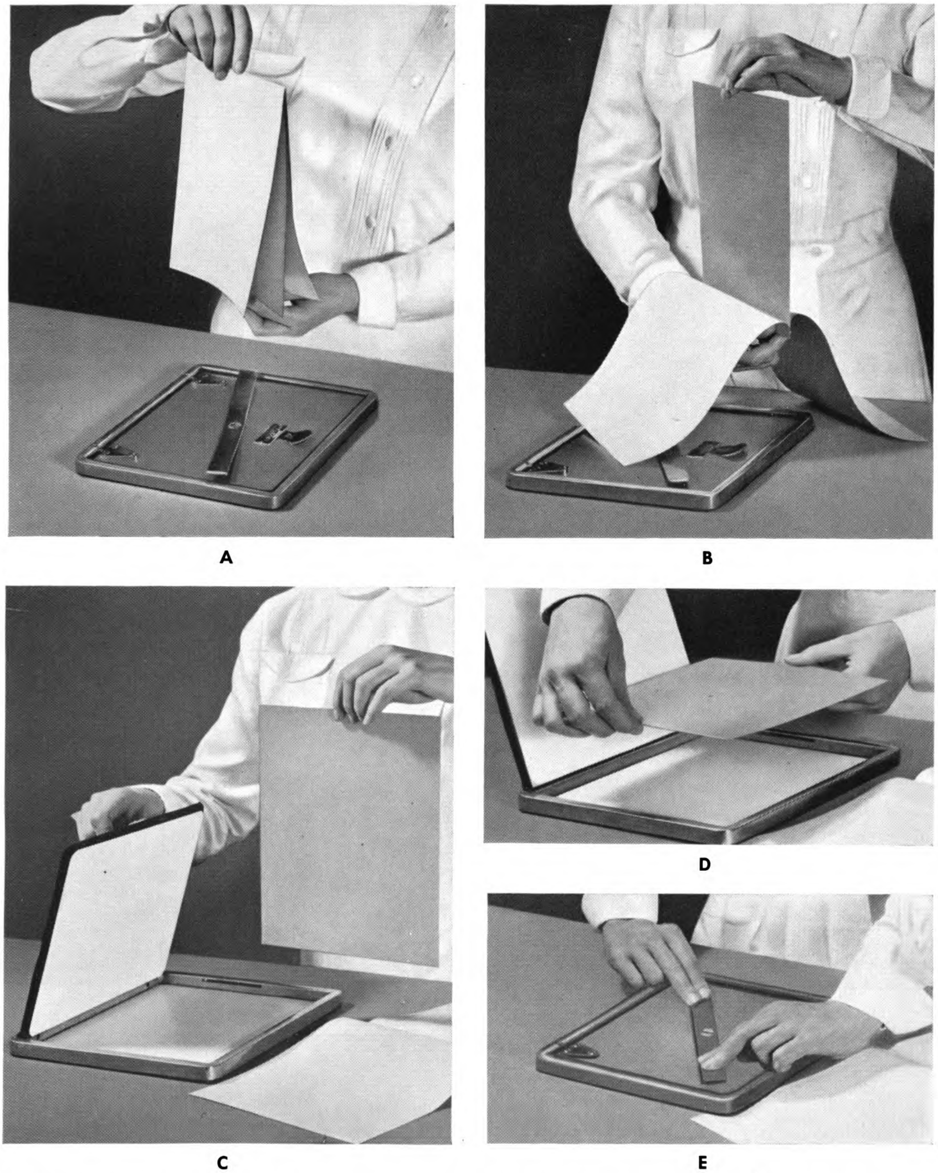


FIGURE 35—Loading cassette containing x-ray intensifying screens:

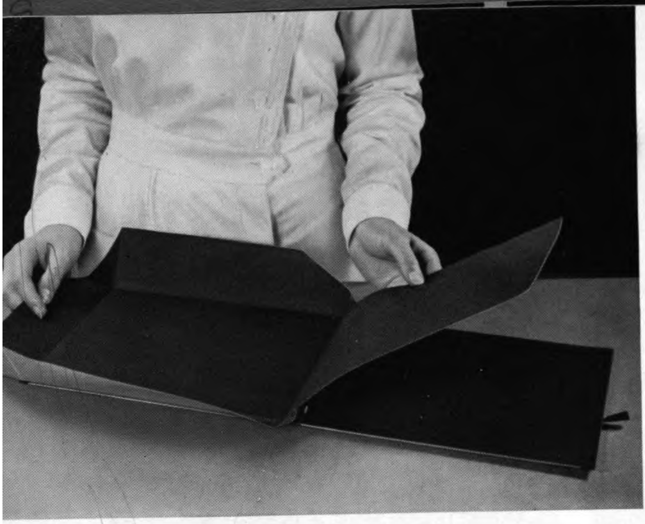
A. Unlock cassette; remove film in its paper folder from box and hold it vertically with right hand. Separate film from paper with left hand and grasp lower edge of film between thumb and forefinger.

B. With left hand still holding its lower edge, turn film clockwise so that paper falls away.

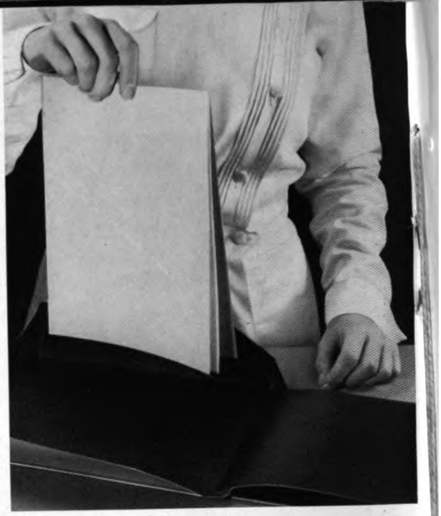
C. Discard paper and open cassette with right hand.

D. Grasp film at center of lower edge with right hand, and, without bending, lay it flat in cassette.

E. Close cassette lid and lock it by spring lever.



A



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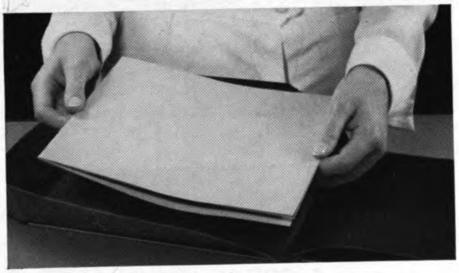

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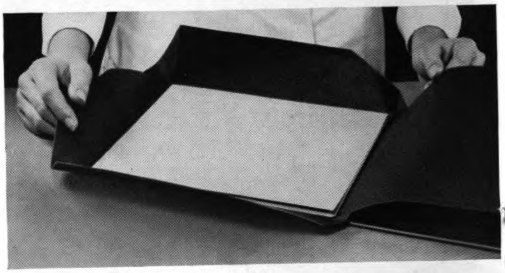

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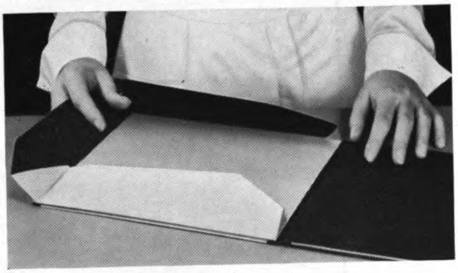

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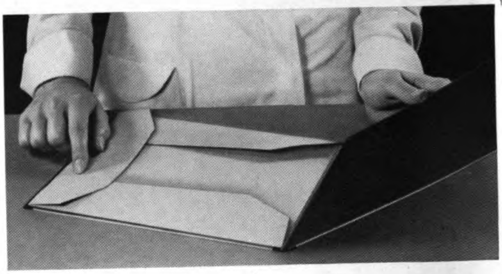

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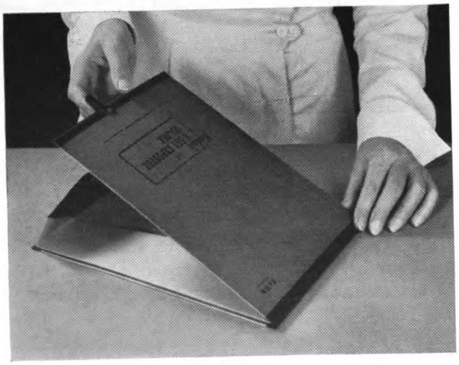

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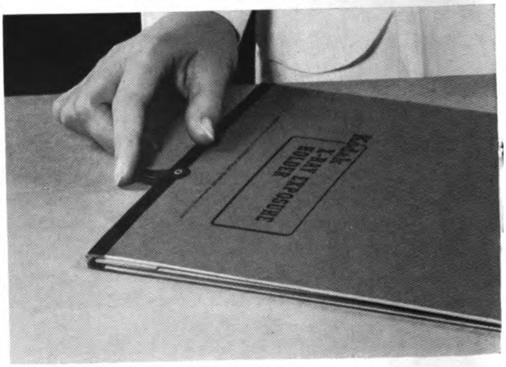

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the bottom flap. The final step is to bring the covers together and fasten them with the clip. (See Figure 36.) It is most important that this procedure of protecting the film be followed if light-fog is to be avoided. The exposure holder is now ready for use.

At the time for radiography, be sure to note the correct side of the holder to present to the tube. Since the back of the exposure holder contains a thin sheet of lead to prevent secondary radiation back-scatter, it must not be interposed between the part and the film. This would cause an underexposure by reason of the absorption of the radiation by the lead. The cover upon which "tube side" is printed should be uppermost and face the x-ray tube.

Film Identification Data

In studying radiographs, the radiologist must be able to determine readily the side of the body examined; the direction of the central ray; and, if stereoradiography is employed, the direction of the tube-shift (SS). An example of such identification is shown in Figure 37. The most effective and accurate way to incorporate these data in the radiograph is by means of markers made of lead or other suitable radiopaque materials that can be placed on the cassette or film holder before the exposure is made. Letters, numerals, and holders for this purpose may be obtained from any dealer in x-ray supplies.

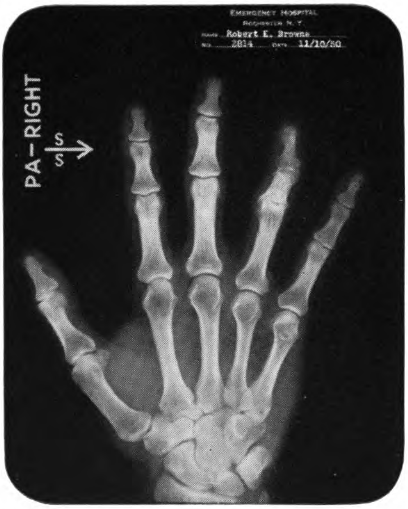


FIGURE 37—Radiograph incorporating data that orients the image and identifies the case.

It is often necessary to incorporate in the radiograph the name and address of the radiologist or institution, the patient's name, the case number, and the date of the examination. From the standpoints of appearance, efficiency, and medicolegal precautions, the photographic method is excellent for such markings. The Kodak X-ray Film Identification Printer is a dependable apparatus for the purpose. It is easily installed in the processing room and is ready for use when plugged into the electric supply line. When the film is processed, the data become an integral part of the radiograph.

FIGURE 36—Loading exposure holder:
A. Unlatch clip of exposure holder; raise back of holder and open paper envelope.
B. Remove film in its protective paper folder from box with right hand and hold it vertically.
C. Grasp film and paper at lower center margin with left hand and, without bending or crimping it, bring it to horizontal position over exposure holder.
D. Lay film and paper carefully in envelope.
E. Fold over top and side flaps of envelope.
F. Fold end flap of envelope into place.
G. Lower back of holder.
H. Latch holder together with metal clip.

Exposure Principles

- X-rays have the ability to penetrate solid objects. The degree of penetration depends on the wave length of the x-rays and the chemical and physical properties of the object through which the radiation passes. If an object is placed between the x-ray source and a film in a lighttight holder, the various internal characteristics of the object are rendered as radiographic *densities* or *tones* on the film after development. The density of a radiographic image, therefore, depends primarily upon the *amount* of radiation reaching the sensitized emulsion of the film *after passage through an object.* The effective intensity of the radiation that will produce a given radiographic density is influenced by: (1) the kilovoltage; (2) the milliamperage; (3) the exposure time; (4) the focus-film distance; (5) the employment of grids, aperture diaphragms, or cones; (6) the intensity of the fluorescent light produced by intensifying screens — when used; (7) the thickness and physiology of the part examined.

X-ray film, like other photographic film, is sensitive to the exposure effect of the radiation of the primary x-ray beam. It is the property of all materials not only to absorb and transmit x-rays in varying degrees but also to scatter them in all directions. These properties were more lengthily described beginning on page 15. X-ray film, being sensitive to all x-radiation, is able to record *both* the effects of the primary x-ray beam which passes through the object and the secondary radiation which is unfocused, aberrant, and generated by the tissues or apparatus struck. The production of the x-ray image can be controlled and is, therefore, acceptable, whereas the fogging effect or supplemental density produced by the secondary radiation is objectionable, unwanted, and can be only partially controlled. It is, therefore, of prime value that the radiographer be able to control exposure factors in order to secure the most desirable results with a minimum of secondary radiation fog on the radiograph.

Radiographic Energy

Since x-rays conform to the laws of light, they diverge when they are emitted from the focal spot, and, proceeding in straight lines, cover an increasingly larger area with *lessened* intensity as they travel from their source. Any change in the distance between the focal spot and the film *(focus-film distance)* influences the intensity of the radiation, which varies inversely as the square of the distance. This principle is illustrated by Figure 38. In this example it is assumed that the intensity of the x-rays emitted at the focal spot (A) remains the same, and that the x-rays passing through the aperture (B) cover an area of 4 square inches on reaching the recording surface (C_1) which is 12 inches (D) from A. Then, when the recording surface (C_1) is moved 12 inches farther from the source, to C_2, so that the distance between A and C_2 is 24 inches (2D), or twice the distance between A and C_1, the x-rays will cover 16 square inches —an area 4 times as great as that on the recording surface at C_1.

It follows, therefore, that the *intensity* of the radiation per square inch on the surface at C_2 is only one quarter that at the level C_1. Thus, the exposure that would be adequate at C_1 must be increased 4 times in order to produce at C_2 a radiograph of equal density. In practice this may be done by increasing the time or increasing the milliamperage.

A change in kilovoltage has considerable effect on the *quantity and quality* of radiation emerging from the object under examination. This radiation is called *remnant radiation* or partially absorbed primary radiation. An increase of kilovoltage produces a marked increase in x-ray penetration; hence, it is necessary to maintain a close control of this factor in order to secure radiographs of uniform density and contrast. It is desirable, as a rule, to use as low a kilovoltage as is consistent with adequate penetration of the object. In general, the thicker parts require the higher kilovoltages; thus, the extremities may be radiographed at 50 to 60 KvP, and the chest at 80 KvP, while in the lateral projection of the lumbar vertebrae 85 KvP may be required. It is not possible to specify a simple relation for the effect caused by changes in kilovoltage because such factors as the thickness and kind of material or tissue radiographed, the characteristics of the x-ray generating apparatus, and whether the film is used alone or with intensifying screens exert a considerable influence on this relationship.

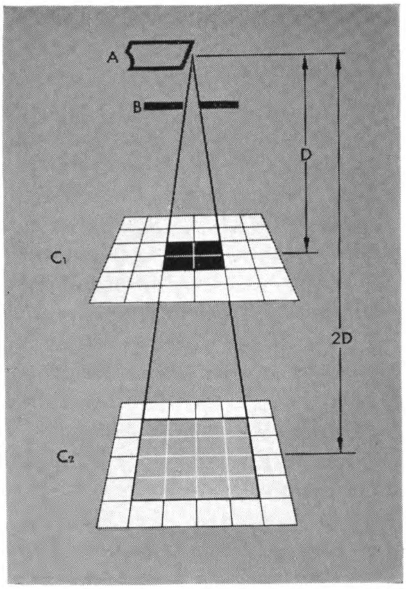


FIGURE 38—Diagram showing relation between focus-film distance and x-ray intensity distribution at two levels.

Determination of Specific Exposure Factors

The focus-film distance is easy to establish by actual measurement; the milliamperage may be determined reliably by the better grades of milliammeters; and the exposure time may be accurately controlled by an efficient time-switch. The tube voltage, however, is difficult to evaluate accurately, and its significance in terms of x-ray output depends considerably upon the characteristics of the generating apparatus. Consequently, while specified exposure technics may be duplicated satisfactorily in the factors of focus-film distance, milliamperage, and exposure time, one apparatus may differ materially from another in the kilovoltage setting necessary to produce the same radiographic effect. Because of this fact, the kilovoltage setting for a given technic should be determined on each x-ray generator by trial or by reference to the kilovoltage calibration furnished by the manufacturer of the apparatus.

It is customary for equipment manufacturers to calibrate x-ray machines at the factory and to furnish suitable exposure charts. In preliminary tests, published exposure charts may be followed as an approximate guide. For the unusual problems that arise, it is desirable to record all data on exposure and technics. In this way the radiographer will soon build up a source of information that will make him more and more competent to deal with difficult situations.

For developing trial exposures, freshly prepared developer solution at a temperature of 68°F., or as near thereto as possible, should always be used. By employing a *standardized processing procedure,* any variation in the quality of the radiographs may then be attributed to the exposure factors. This method obviates many of the variables in radiography.

Arithmetic of Exposure

When an x-ray generator is installed, suitable exposure charts for all body parts in their various projections must be established. Existing exposure charts, based on results from other generators, may be used as a guide, but the final data are obtained by experience with the individual installation. Occasionally, for some special purpose, it is necessary to modify some factor of the customary exposure technic, such as focus-film distance, milliamperage, kilovoltage, or exposure time, and an estimation must be made of the change required in one of the other factors in order to maintain a desired radiographic effect. It is not always possible to determine these changes accurately, but the following examples illustrate the methods commonly used in solving such problems.

The calculations for any changes in focus-film distance, milliamperage, or time are matters of simple application of formulas.

Milliamperage-Distance Relation

The milliamperage employed in any exposure technic should conform to the manufacturer's rating of the tube.

The milliamperage required for a given exposure is directly proportional to the square of the focus-film distance if other factors are constant. This rule may be expressed in the following formula:

$$\frac{\text{(A) original MA}}{\text{(B) new MA}} = \frac{(C^2)\text{ original distance}^2}{(D^2)\text{ new distance}^2}$$

Example: Suppose that 50 milliamperes (A) and a focus-film distance of 36 inches (C) have been employed, and it is desired to increase the distance to 72 inches (D) in order to obtain sharper definition. What milliamperage (B) would be required?

Solution: Since A, C, and D are

known but B is unknown, by transposition of the above basic formula, the following equation is obtained to solve the problem:

$$B = \frac{AD^2}{C^2} = A\left(\frac{D}{C}\right)^2$$

Substituting numerical values in the above equation and changing inches to feet, the solution is readily made:

$$B = 50 \times \left(\frac{6}{3}\right)^2 = 50 \times 2^2 = 200 \text{ milliamperes}$$

Example: Suppose that 100 milliamperes (A) and a focus-film distance of 72 inches (C) have been employed with a large focal-spot x-ray tube, and it is desired to change to a smaller-focus tube designed to operate at a considerably lower milliamperage. The milliampere factor selected is 20 (B); what distance (D) would be required?

Solution: Since A, B, and C are known but D is unknown, by transposition of the basic formula, the following working equation is obtained to solve the problem:

$$D^2 = \frac{BC^2}{A}$$

$$D^2 = \frac{20 \times 72^2}{100} = \frac{103680}{100} = 1036.8$$

$$D = 32 \text{ inches (approx.)}$$

or by the square-root method:

$$D = C\sqrt{\frac{B}{A}}$$

$$D = 72\sqrt{\frac{20}{100}} = 72\sqrt{.20}$$

$$D = 72 \times .45$$

$$D = 32 \text{ inches (approx.)}$$

Milliamperage-Time Relation The milliamperage required for a given exposure is inversely proportional to the exposure time. The rule is expressed in the following formula:

$$\frac{\text{(A) original MA}}{\text{(B) new MA}} = \frac{\text{(F) new time}}{\text{(E) original time}}$$

Example: Suppose that 30 milliamperes (A) and an exposure time of ½ second (E) have been employed, and it is desired to decrease the exposure time to 1/20 (.05) second (F). What milliamperage (B) would be required?

Solution: Since A, E, and F are known but B is unknown, the following equation is obtained from the formula to solve the problem:

$$B = \frac{AE}{F} = \frac{30 \times .5}{.05} = \frac{15}{.05} = 300 \text{ milliamperes}$$

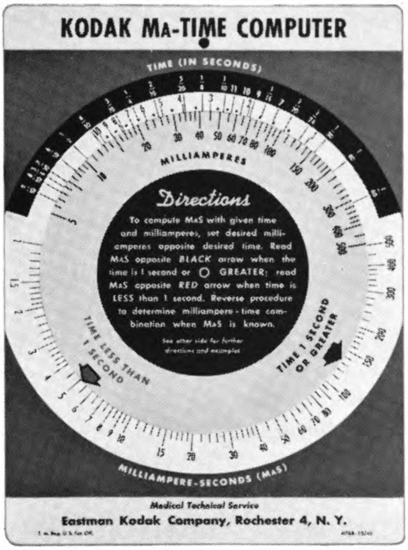
Since the *quantity* of radiation is essentially a product of milliamperage and time, it is often expressed as milliampere-seconds (MAS). In the preceding example, the intensity can be expressed as the product of 300 milliamperes multiplied by 1/20 second, or 15 MAS.

Example: Suppose that 30 milliamperes (A) and an exposure time of 2 seconds (E) have been employed, and it is desired to increase the milliamperage to 60 (B). What exposure (F) would be required?

Solution: Since A, B, and E are known, but F is unknown, the following equation is obtained from the basic formula to solve the problem:

$$F = \frac{AE}{B} = \frac{30 \times 2}{60} = 1 \text{ second}$$

A device (Figure 39, page 64) that simplifies computations regarding time, milliamperage, or milliampere-seconds is available free from



Directions

To compute MAS with given time and milliamperes, set desired milliamperes opposite desired time. Read MAS opposite BLACK arrow when the time is 1 second or GREATER; read MAS opposite RED arrow when time is LESS than 1 second. Reverse procedure to determine milliampere-time combination when MAS is known.

See other side for further directions and examples

FIGURE 39

your Medical Division representative or the *Medical Technical Service,* Eastman Kodak Company, Rochester 4, N. Y. It is called the Kodak MA-Time Computer (MTS-8). Made of stiff cardboard laminated with Kodapak, it will resist the wear that such a useful device will experience.

Time-Distance Relation The exposure time required for a given exposure is directly proportional to the square of the focus-film distance. This rule may be reduced to the following formula:

$$\frac{\text{(E) original time}}{\text{(F) new time}} = \frac{(C^2)\text{ original distance}^2}{(D^2)\text{ new distance}^2}$$

Example: Suppose that an exposure time of 10 seconds (E) and a focus-film distance of 30 inches (C) have been employed, and it is desired to decrease the focus-film distance to 24 inches (D). What exposure time (F) would be required?

Solution: Since E, D, and C are known but F is unknown, the equation below derived from the formula given may be used:

$$F = \frac{ED^2}{C^2} = E\left(\frac{D}{C}\right)^2 = 10\left(\frac{24}{30}\right)^2 = 10\left(\frac{8}{10}\right)^2 =$$
$$10 \times .64 = 6.4 \text{ seconds}$$

Example: Suppose that an exposure time of 2 seconds (E) and a focus-film distance of 6 feet (C) have been employed, and it is desired to decrease the exposure time to ¼ (.25) second (F). What distance (D) would be required?

Solution: Since E, F, and C are known but D is unknown, the equation below derived from the above formula may be employed:

$$D^2 = \frac{FC^2}{E}$$
$$D^2 = \frac{.25 \times 6^2}{2} = 4.5 \text{ ft.}$$
$$D = 2.1 \text{ feet}$$

or by the square-root method:

$$D = C\sqrt{\frac{F}{E}} = 6\sqrt{\frac{1/4}{2}} = 6\sqrt{\frac{1}{8}}$$
$$D = 6\sqrt{.125} = 6 \times .35$$
$$D = 2.1 \text{ feet}$$

Milliamperage-Time and Distance Relation Since the milliamperage and the time required for a given exposure are both directly proportional to the square of the focus-film distance, the product of the two, milliampere-seconds (MAS) is also directly proportional to the square of the focus-film distance.

This rule may be reduced to the following formula:

$$\frac{\text{(R) original MAS}}{\text{(S) new MAS}} = \frac{(C^2)\text{ original distance}^2}{(D^2)\text{ new distance}^2}$$

Exposure Conversion Factors for Changes in Focus-Film Distance

INITIAL FOCUS-FILM DISTANCE	DESIRED FOCUS-FILM DISTANCE							
	20 in.	*25 in.*	*30 in.*	*36 in.*	*40 in.*	*48 in.*	*60 in.*	*72 in.*
20 in.	1.00	1.56	2.25	3.22	4.00	5.76	9.00	12.96
25 in.	.64	1.00	1.44	2.07	2.56	3.68	5.76	8.29
30 in.	.44	.69	1.00	1.44	1.77	2.56	4.00	5.76
36 in.	.31	.48	.69	1.00	1.23	1.77	2.77	4.00
40 in.	.25	.39	.56	.81	1.00	1.44	2.25	3.24
48 in.	.17	.27	.39	.59	.69	1.00	1.56	2.25
60 in.	.11	.17	.25	.36	.44	.64	1.00	1.44
72 in.	.08	.12	.17	.25	.31	.44	.69	1.00

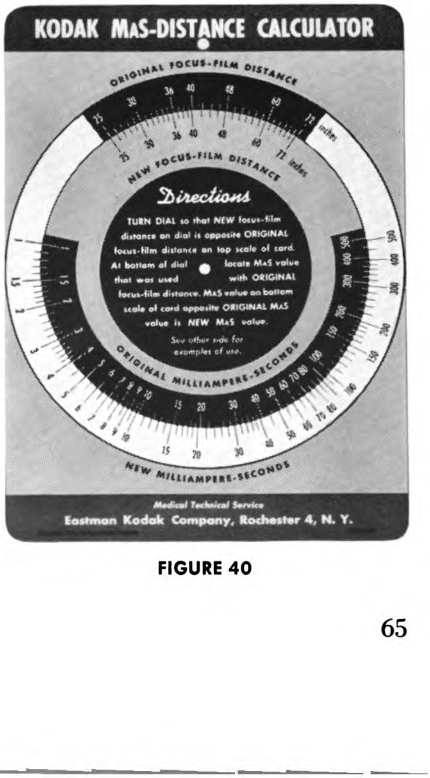
Example: Suppose that 60 milliampere-seconds (R) and a focus-film distance of 3 feet (C) have been employed, and it is desired to increase the focus-film distance to 6 feet (D). What milliampere-seconds factor (S) would be required?

Solution: Since R, C, and D are known but S is unknown, the equation below may be used.

$$S=\frac{RD^2}{C^2}=R\left(\frac{D}{C}\right)^2=60\left(\frac{6}{3}\right)^2=60(2)^2=60\times4=240\ \text{MAS}$$

The interrelation of all focus-film distances may be expressed by means of a conversion factor. Any change in milliampere-seconds necessitated because of a change in the focus-film distance may then be calculated by multiplying, by the proper factor, the initial milliampere-seconds value. The table above lists the factors that apply for focus-film distances commonly employed in radiography. To use it, the initial focus-film distance is located in the left-hand vertical column and the desired distance is located in the horizontal column at the top of the chart. The required conversion factor will be found in the square common to both columns.

A handy calculator (Figure 40) for compensating MAS for changes in focus-film distance may be obtained free of charge from the Medical Division representative who calls at your laboratory or by requesting it from the *Medical Technical Service,* Eastman Kodak Company, Rochester 4, N. Y. Ask them to send you a copy of the Kodak MAS-Distance Calculator (MTS-5).



Directions

TURN DIAL so that NEW focus-film distance on dial is opposite ORIGINAL focus-film distance on top scale of card. At bottom of dial locate MAS value that was used with ORIGINAL focus-film distance. MAS value on bottom scale of card opposite ORIGINAL MAS value is NEW MAS value.

See other side for examples of use.

Medical Technical Service
Eastman Kodak Company, Rochester 4, N. Y.

FIGURE 40

Relation Between Kilovoltage and Time It is frequently necessary to *estimate* the kilovoltage for a given change in exposure time, or determine the approximate change in exposure time necessary to compensate a change in kilovoltage. While it is not possible to give an exact rule for all cases, the table "Kilovoltage-Time Relation," provides estimates of the corrections that should be applied to kilovoltage or time when either is changed. It must be kept in mind that an increase in kilovoltage with the exposure adjusted to maintain the same density of radiograph will produce lower contrast in the radiograph, and conversely, a decrease in kilovoltage will produce higher contrast.

Example: Suppose that with intensifying screens a kilovoltage of 80 and an exposure time of 4 seconds have been employed, and it is desired to decrease the exposure time to 2 seconds. What kilovoltage is required?

According to the table, the decrease in exposure time is 50 per cent which necessitates a 20 per cent increase in kilovoltage:

20% of 80 KvP = 16 KvP
80 KvP + 16 KvP = 96 KvP

Kilovoltage-Time Relation

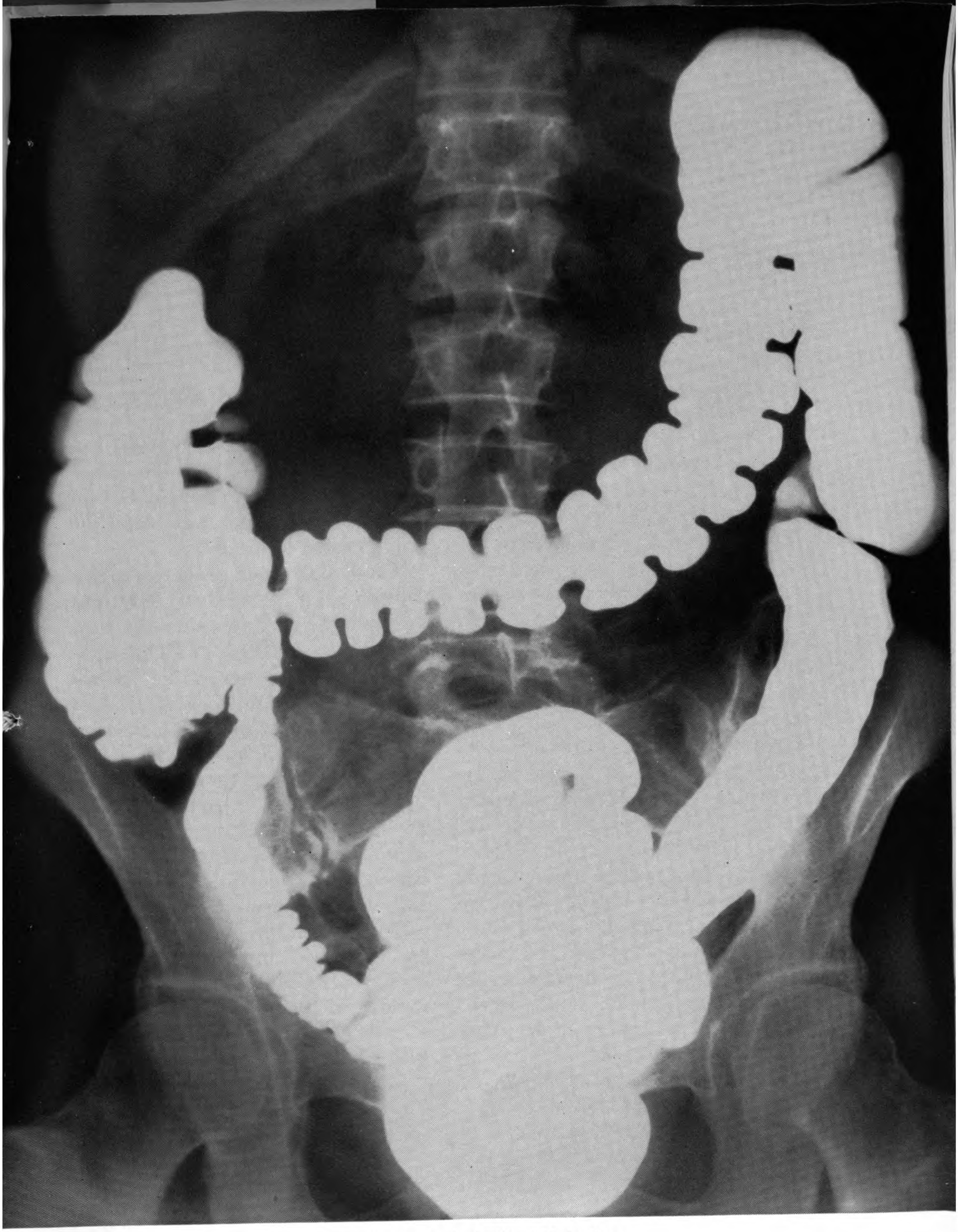
To Decrease Exposure Time	Increase Kilovoltage	
	With Double Screens	*Without Screens*
25%	7%	15%
50%	20%	40%
75%	50%	100%
To Increase Exposure Time	Decrease Kilovoltage	
	With Double Screens	*Without Screens*
25%	5%	10%
50%	10%	18%
75%	13%	25%
100%	16%	30%

Example: Suppose that with intensifying screens a kilovoltage of 80 and an exposure time of 4 seconds have been employed, and it is desired to decrease the kilovoltage to 70. What exposure time would be required?

The decrease in kilovoltage is about 13 per cent, which necessitates a 75 per cent increase in time.

75% of 4 sec. = 3 seconds
4 sec. + 3 sec. = 7 seconds

Influence of Intensifying Screens on Exposure When intensifying screens are used with Blue Brand X-ray Film, they permit reduction of the exposure to a fraction of that needed for the same film in direct-exposure technic (without screens). The percentage of reduction is not constant, being dependent upon the "speed" of the screens, the kilovoltage, and the part radiographed.



Radiograph of a barium-filled colon.

Processing Room

• Too much thought cannot be given to the proper planning of the processing room. In order that the exposed films may be handled expeditiously and the best possible quality obtained regularly in the radiographs, this room should be completely equipped in every detail. *It is not consistent to invest thousands of dollars in efficient x-ray equipment and not give due attention to the provision of adequate space and apparatus for processing the films.*

Planning the Processing Room In assigning space for the processing room, proper consideration should be given the volume of work to be performed in it. In Figure 41 are shown two views of a typical processing room in which about 120 14x17-inch films can be handled per day. This amount of developing can be done in a 6-gallon tank, but to avoid too frequent renewal of developer solution the use of a larger tank, or two or more 6-gallon tanks, is more practical. With such an arrangement, the capacity of the fixing compartment should be approximately twice that of the developer solution tank, or at least 12 gallons; and the washing tank should hold from 18 to 20 gallons. The use of two drying compartments holding 10 film hangers each is indicated. Details of these drawings may be secured on request to *Medical Technical Service,* Eastman Kodak Company, Rochester 4, N. Y.

In the interest of efficiency, the floor space should be as small as is practicable, and the arrangement in general should follow the plans shown so that dry films, holders, and cassettes will be kept away from the solution-side of the room.

Processing rooms generally have a labyrinth, or a two-door lighttight vestibule. This is necessary if access is to be extended to all who are handling films. If, however, the processing is to be done by one person, a single door, which can be locked on the inside, may be sufficient.

The processing room should, if possible, adjoin the room in which the radiographs are made, and have a film-transferring cabinet in the wall between. This makes loaded holders and cassettes easily available to the radiographer, and the exposed film can be passed through to the processing room. Such an arrangement reduces traffic in the room, and permits the work there to be carried on without interruption.

The film bin illustrated in these plans is an ideal place to store opened boxes from which film holders are loaded. It is lighttight, closes automatically, and makes film easily available for most efficient loading.

Drawings and Plans Copies of the drawings shown in Figure 41, in ad-

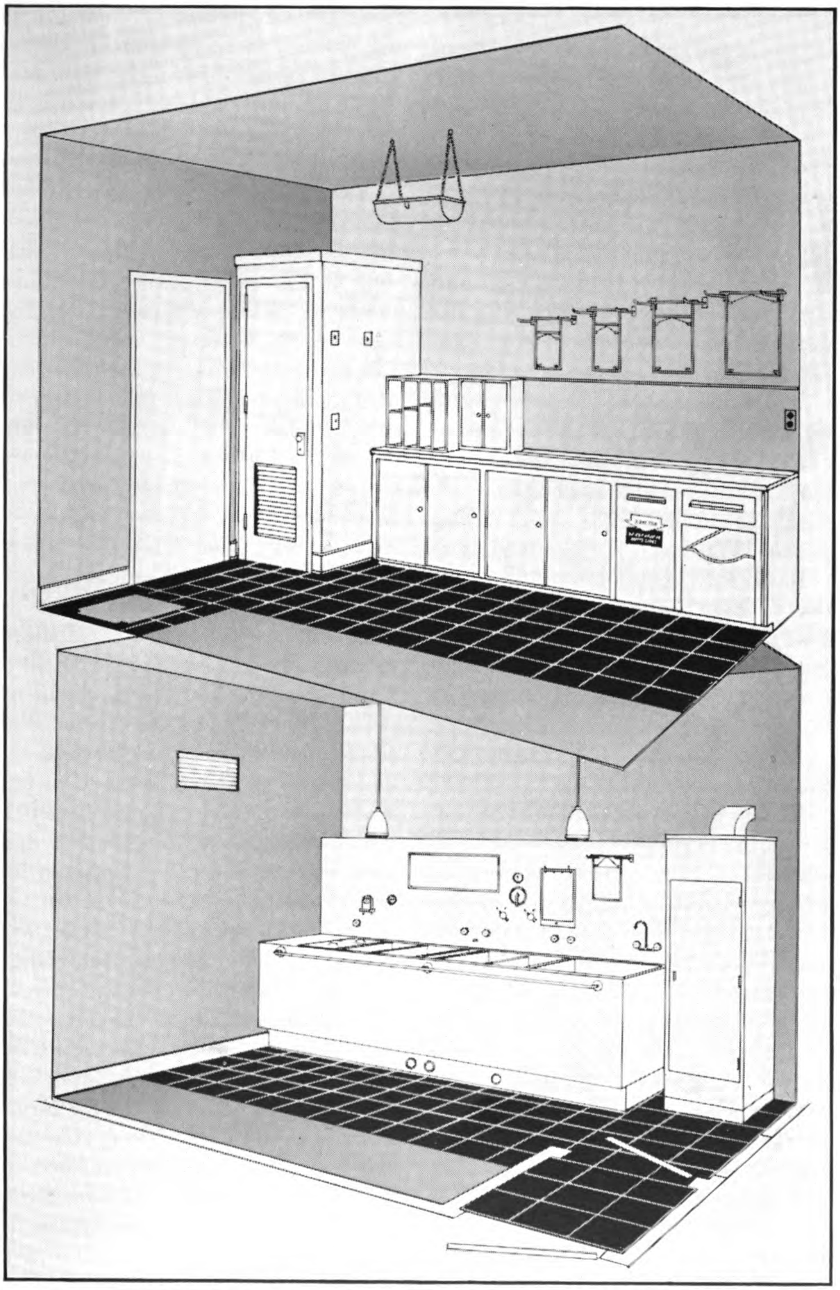


FIGURE 41—Perspective views of a typical processing room. **ABOVE:** Film-handling arrangement. **BELOW:** Tank arrangement.

dition to several other detail drawings, can serve as a guide in planning your processing room and may be procured upon request. Although various components of the processing room may be constructed by an able carpenter, most of the items illustrated may be purchased from your x-ray equipment dealer.

Finish The finish of the processing room should be carefully chosen, because two distinct requirements must be met. The floor and walls to at least a few inches above the tanks should be protected against the action of chemical solutions and water that may be spilled or splashed on them. And the upper walls and ceiling should be painted so that the maximum of safe illumination will be reflected from them.

Equipment Any modern tank system that permits control of the solution temperature is satisfactory. The tanks must be of a corrosion-resistant material that does not contaminate the processing solutions.

The drying of films is always important; therefore, considerable attention has been directed to the film-drying cabinets suggested in the plans. The blower compartment should be fitted with heating elements and a large fan. As a precaution, the heating elements should be connected in the fan circuit to prevent turning on the heat without activating the fan. Incidentally, the arrangement shown is also helpful in the ventilation of the room.

Proper ventilation is essential. Processing rooms should be ventilated by the over-all system normally existing in large buildings or by ducting directly to the outside air. Constant circulation of clean, fresh air makes the room more healthful and the routine less fatiguing.

Where only a small number of films are processed daily, a convenient rack for holding hangers during drying can be made by drilling 3/8-inch holes about 4 inches apart in a 1x3-inch board of a length that will fit the space where it will be mounted. When the rack is placed high on the wall, the films can be suspended by inserting the crossbars of the film hangers in the holes. This obviates danger of striking the radiographs while wet, or spattering water on the drying surfaces and spotting them.

Accessories Two enameled pails, several glass funnels, and two wood or stainless steel paddles about 36 inches long should be provided for mixing, pouring, and stirring solutions. Several water- and chemical-proof Kodak Darkroom Aprons also should be available to protect the clothing. The apron is made in two sizes, of tough black vinyl plastic with edges bound in white. A drip cuff, extending the full width of the bottom edge, protects the shoes and clothing. A large utility pocket and a waist cord add to its convenience.

For efficiency in emptying solution tanks that do not have an outlet, an inexpensive washing machine filler and drainer-type water pump may be purchased from one of the larger hardware dealers. This device usually consists of a three-branched rubber hose, one branch for connecting to a water faucet and the others for placing in the solution tank and in the sink, respectively. When the faucet is turned on, enough suction is generated by the running water to drain the tank rapidly. The pump can also be used in the cleaning of tanks by rinsing them with water entering through the outlet branch, and then removing the water through the suction branch.

Illumination Safelight lamps are an indispensable item in every processing room. Their function is to provide an abundance of *safe* light for use during the handling and processing of x-ray film. Of course, no safelight is safe if the standards of safety are abused. Film left out under a safelight lamp too long will fog. If film cannot be developed at once, it should be carefully covered with interleaving paper and stored in a lighttight container.

When loading films in hangers preparatory to group development, it is important that they be safeguarded against direct radiation from the lamps. Exposed films should be set to one side away from the direct beam of a safelight lamp, or better still, placed under or behind a protective screen. Films should never be stacked in hangers and left standing under a safelight lamp. If this is necessary, the hangers containing the films should be covered with black paper so as to shield them from the action of the safelight. If the films cannot be covered, the safelight nearest the stacked films should be turned off.

As far as practicable, the general illumination should be made indirect by suspending from the ceiling one or more safelight lamps of appropriate design and size; if the walls and ceiling are painted with a light colored paint, the entire room will be well lighted with safe illumination.

For light in specific sections of the processing room, there are Kodak-made safelight lamps of various designs. The choice and arrangement of the lamps should depend upon the amount of illumination desired and the angle at which it must fall.

Kodak Safelight Filters, Wratten Series 6B, are recommended for use in all direct and indirect safelight lamps. They provide maximum illumination, to which the eyes easily adapt themselves.

Checking Safety Certain considerations must be kept in mind in connection with safelight lamps and safelights. First, the illumination will be safe only if bulbs of the wattage indicated on each lamp are used. Second, all safelight filters are safe only as long as specific conditions prevail. The standard of safety for all Kodak safelight filters is such that unexposed sensitized materials for which they are recommended may be handled in the light at a distance of 3 feet, for 1 minute. Consequently, these factors apply to the use of the Wratten Series 6B filters, with unexposed x-ray film. Screen-exposed films are nearly 8 times as sensitive to the illumination from safelight lamps as are unexposed films.

A simple method of checking the safety of illumination is to cover part of a film and expose the remainder for different lengths of time in the place where films will be uncovered in handling, and then to give this test film standard development. If no fog shows on the parts that received a reasonably long exposure, as compared with the covered part, the lighting may be assumed to be safe.

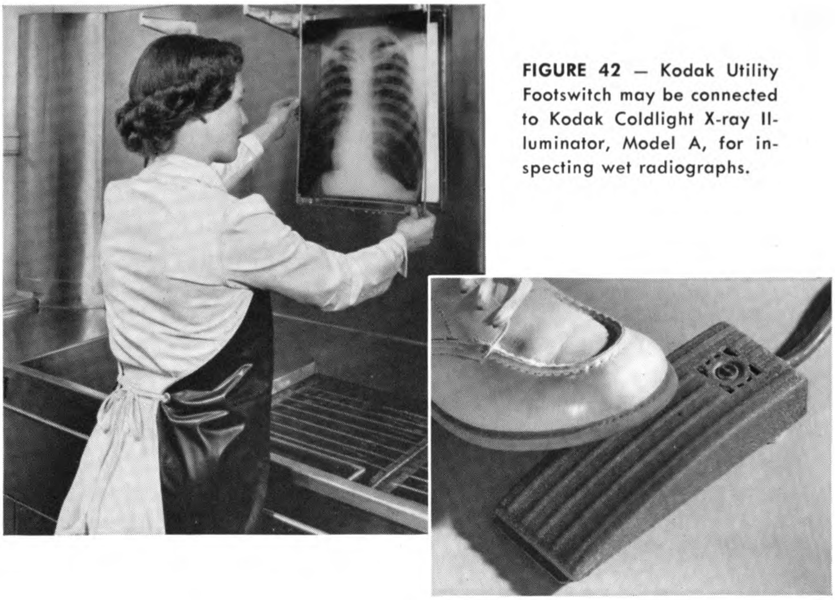


FIGURE 42 — Kodak Utility Footswitch may be connected to Kodak Coldlight X-ray Illuminator, Model A, for inspecting wet radiographs.

Viewing Light When it is necessary to inspect films during the course of hardening and washing, a recessed Kodak Coldlight X-ray Illuminator, Model A, connected to the current supply through a Kodak Utility Footswitch will be found to be convenient (Figure 42). The light can be instantly controlled without use of the hands. The illuminator should not, of course, be switched on when unprotected and unprocessed films are on the loading bench. Radiographs must not be inspected until they have been cleared in the fixer.

Cleanliness The sensitiveness of x-ray film emulsions make cleanliness imperative. The processing room, as well as the accessories and equipment must be kept scrupulously clean, and used only for the purposes intended. Spilled solutions should be wiped up at once; otherwise, upon evaporation, the chemical dust may rise in the air and later settle on film or screen surfaces and cause artifacts on the radiographs.

Since cleanliness is of importance and the presence of extraneous marks or artifacts on the radiograph are objectionable, residual gelatin or dirt in the clips should be removed periodically. Methods for cleaning hangers are discussed on page 113. The repair of hangers is most efficiently accomplished by the manufacturer. Hangers may be shipped through x-ray supply dealers for repair.

Processing

• The cost and elaborateness of x-ray equipment are not the only criteria that determine the *quality* of the radiographs produced with it. Even though the efficiency of the apparatus is of the highest, and the best exposure practice is followed, the radiograph will be of inferior quality if the processing procedure is inadequate and inefficient.

The greatest error in the production of the radiograph often may be a flagrant disregard of the simplest of processing rules. Therefore, knowledge concerning the proper handling and care of x-ray film, and its correct processing, should be expected of every radiographer.

As stated in preceding sections of this book, modern x-ray film consists of a special silver halide emulsion coated on both sides of a cellulose acetate base, in layers about .001 inch thick. When the film is subjected to x-rays, a change takes place in the silver halide salts: those that have been exposed to the rays are capable of being converted into an image of black metallic silver through the action of a chemical solution, called developer; those crystals that are unexposed can be removed by additional treatment in another chemical solution, called fixer. Processing represents the various steps — development, rinsing, fixation, washing, and drying — that bring about the chemical changes that render visible as a radiographic image the latent image created by the x-rays.

When the x-ray film is subjected to the action of x-radiation, the silver halide crystals which have been "exposed" contain the *latent* image. The latent image cannot be observed or detected by any physical means, but it can be made visible by a chemical treatment known as *development.* The crystals containing the latent image are thereby converted into finely dispersed black metallic silver. The blackening, which depends upon the *intensity* of the x-rays reaching the film and the duration of exposure, consists of minute particles of metallic silver that collectively constitute *radiographic density.* These densities compose the image as normally seen on the radiograph. Those crystals which are *not* affected by the action of the x-rays are removed by the *fixing bath,* which has no effect on the black metallic silver produced by the developer.

Mixing Solutions

The first step in the processing procedure is the proper preparation of the developing and fixing solutions. When mixing the chemicals to be made into these solutions, the manufacturer's directions found on the label of the container should always be carefully followed if best results are to be obtained. There are, however, some general recommendations which it is necessary to observe when making up solutions:

1. The temperature of the water in which the chemicals are to be dissolved should never exceed that shown on the label of the package.

2. The containers for mixing the chemicals should consist of corrosion-resistant materials such as good enamel or glazed earthenware, glass, hard rubber, and types 304, 316, and 317 stainless steel; vessels made of tin, copper, zinc, aluminum, or galvanized iron should be avoided.

3. The water should always be poured into the tank or pail and the chemicals added slowly while the mixture is stirred vigorously, permitting the chemicals to go into solution quickly without "caking" or "lumping" of the ingredients; the creation of clouds of chemical dust by rapid pouring of the dry chemical into the water should be avoided.

4. When the chemicals are entirely dissolved, sufficient cold water should be added to bring the solution to the correct volume and temperature, thorough stirring being necessary to mix the cool water with the chemical-laden solution already present; solutions should not be used until all the chemicals are thoroughly dissolved and at the optimum temperature of 68°F.

5. If the solution is not for immediate use, it should be placed in a clean bottle of the proper size, well stoppered and labeled plainly; developer should be stored in brown bottles, away from radiators, for heat may cause deterioration of the solution.

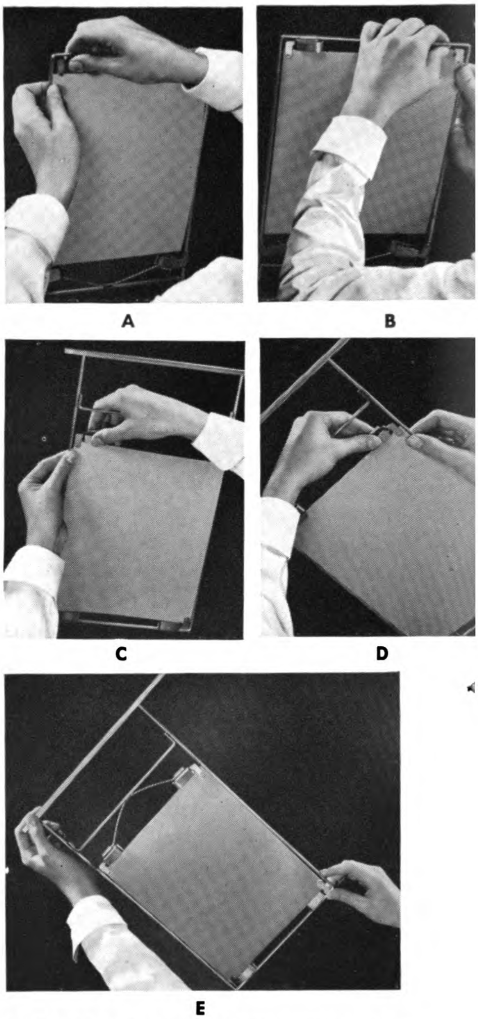


FIGURE 43—Loading Kodak X-ray Processing Hanger, No. 3:

A. Attach left clip of inverted hanger to film.
B. Attach right clip to film.
C. Reverse hanger and attach left clip to film.
D. Attach right clip to film.
E. Check to be sure film is taut.

6. Separate wooden paddles for the developer and for the fixer should be employed for mixing purposes,

after which they should be washed with clear warm water and hung up to dry. (If available, stainless steel, 18-8, paddles are to be preferred.)

7. When mixing solutions, tanks or other containers that have been soldered should not be used, because the metals in solder will tend to dissolve and cause chemical fog on film.

8. To ensure the proper concentration of solutions, the *volume* in gallons of the tank should be accurately computed. This is done by dividing the product of the *inside* dimensions of the tank (width × breadth × depth minus 1 inch) by 231.

9. Processing tanks should be thoroughly cleaned before fresh solutions are placed in them. See "Cleaning Processing Equipment," page 111.

10. The developer tank should be fitted with a cover to reduce the amount of air in contact with the solution, keep out foreign matter, and reduce the rate of evaporation; covers may be made of hard wood soaked in paraffin, and should be constructed so as to fit over the top of the tank or float on the solution.

TANK PROCESSING

There are two methods for processing x-ray films: the *tank* and the *tray* methods. The tank method is more efficient and convenient and is employed in virtually every x-ray laboratory. The tray method is used largely as an emergency measure especially in rapid processing of surgical radiographs.

The advantages of tank processing are many, the most important being that it provides facilities for maintaining constant temperature, and for more efficiently preserving the solutions.

In this system, tanks containing the developer and fixer are properly located in a master tank containing water at the prescribed temperature. Sufficient space is provided so that a place for film rinsing and washing is available in addition to the solution tanks. Water is circulated in the master tank at a temperature that is controlled by a mixing valve situated in the hot- and cold-water supply.

Preliminary Steps When exposed film is taken to the processing room, the temperature of the solutions is determined and adjusted to 68°F. All white light is eliminated and safelight lamps transmitting light through Kodak Safelight Filters, Wratten Series 6B, are switched on.

The film is next removed from the cassette or exposure holder and mounted in a stainless steel developing hanger. (The paper is removed from around the film and discarded.) Kodak X-ray Processing Hangers, No. 3, consist of a rigid frame to which four clips are attached, two of which are mounted on a bow spring welded to a top crossbar. When the exposed film is removed from the cassettes or exposure holder, it is held vertically with the right hand at the upper left corner while a hanger of proper size is taken from the storage rack. The upper left corner of the film is inserted in the left clip, and the right film corner in the right clip (Figure 43A-B). The hanger is then inverted and the procedure is repeated (Figure 43C-D). The bow spring serves to keep the film taut and straight during processing.

The film is now ready to be developed, but before immersing it in the developer, the surface of the film should be checked to see that it is taut and does not bulge (Figure 43E). If bulging is present, one of the upper bow spring clips should be loosened and the film reinserted in the clip after the slack has been carefully taken up.

There are several ways in which a film may be developed but the standard time-temperature method is almost universally employed. This method is most efficient, for it is virtually foolproof and is an excellent means of checking on exposures.

Development

The development of an x-ray image is a chemical process whereby the exposed silver halide crystals are reduced to metallic silver in the emulsion of the film. A developer is a reducer — a material or solution that can be readily oxidized. Reducing agents are important in photography, for such substances in solution, added to a silver solution, will cause the formation of metallic silver. This is essentially the function of an x-ray developer.

It is necessary that an x-ray developer be *selective* in its action and be able to reduce the *exposed* silver halide crystals to black metallic silver, but not the unexposed crystals. An x-ray developer contains four types of ingredients:

1. The *developing agents* or reducers serve to reduce or free the silver from the *exposed* silver halide crystals; they do not affect the unexposed crystals. The agents commonly employed in x-ray developers are *elon* and *hydroquinone*. The activity of these chemicals requires their presence in an alkaline solution. The elon selects or attacks the silver halide crystals that contain the latent image and starts their development. The hydroquinone accelerates this action by helping the elon to reduce the silver and build up the density.

2. The *preservative* is employed to prevent the developer solution from oxidizing in the presence of air. The chemical used is *sodium sulfite.* This chemical minimizes oxidation of the developing agents.

3. The *activator* or alkali softens the gelatin of the emulsion and provides the necessary alkaline medium to the solution so that the developing agents can attack the silver halide crystals. The chemicals most frequently used are *sodium carbonate* or the alkali, Kodalk.

4. The *restrainer* inhibits the fogging tendency of the solution. The chemical usually employed for this purpose is *potassium bromide* which prevents action of the developing agents on the unexposed silver halide crystals. Like the activator, the potassium bromide assists in controlling the duration of development.

Developers are available in packaged form — liquid and powder — each containing the necessary ingredients so that preparation of a solution is a simple matter. No longer must the radiographer painstakingly weigh out the necessary quantities of individual chemicals. Today, he need only read the instructions on the package and mix the contents accordingly.

Kodak products of these two types are as follows: the liquids are Kodak

Liquid X-ray Developer and Replenisher and Kodak Concentrated Dental X-ray Developer; the powders are Kodak Rapid X-ray Developer and Kodak X-ray Developer. All are characterized by uniformity and long life. Therefore, the choice in use is influenced by the individual qualities of each.

Exhaustion System The chemical reactions involved in the processing procedure should take place within a limited time and temperature range for optimum results. Then, the effects of over- or underexposure may be observed and the best in exposure technic obtained. Although the latitude of the film will compensate in a measure for some errors in exposure, good-quality radiographs cannot be secured if hit-or-miss methods in processing are employed.

Processing by inspection opens avenues of error through which the quality of the finished radiograph may easily become impaired. As an illustration, the radiographer's visual acuity in the processing room is dependent largely upon his physical condition. Fatigue, inefficient accommodation of the eyes to sudden changes in light intensity, poor location of safelight lamps — all tend to make uniform results impossible.

Uniformity in radiographic densities and equal densities that are desired in comparative films are only obtained when the standard, *time-temperature* method of development is employed. With time-temperature processing, when the time and temperature are known to be correct, films lacking density are the result of underexposure, not underdevelopment; and those having excessive density are the result of overexposure and not overdevelopment. By avoiding variables in development, suitable changes in the exposure factors can be made so that good-quality radiographs are secured.

The time of development has a direct relation to the *activity* of the developer solution, particularly with regard to its degree of exhaustion. For example, the reliability of the recommended normal development intervals for Blue Brand Film is valid only as long as the solution has its original developing power, because the chemicals are gradually exhausted through their action on the films. In order to continue to obtain radiographs that show as satisfactory development as the initial ones, adjustment to a longer interval must be made to compensate the diminishing activity of the chemicals. An indispensable item in processing is a suitable timing device. It may be secured from your x-ray dealer.

Chemical reactions are stimulated or retarded as a result of temperature. Since processing is essentially a chemical reaction, the temperature of the solutions employed should be carefully regulated. Variations in temperature require adjustment in the time factor so that adequate radiographic densities may be shown.

Temperatures should not be estimated; the optimum temperature of 68°F. recommended by the American Standards Association has been adopted. Obviously, a good thermometer is essential if temperatures of solutions are to be checked accurately. Kodak Tank and Tray Thermometer (Figure 44, page 78) is a sturdy, easily read instrument. Its

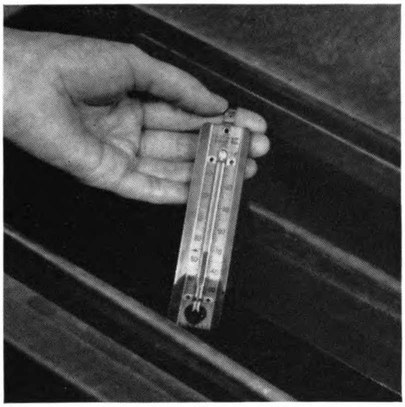


FIGURE 44

pivoted spring clip can be formed into a hook so that it can be hung over the side of the tank when not in use. The temperature of the solutions should *always be checked* when the work is first begun, and at intervals during the day to be sure the proper temperature is being maintained.

A temperature below 68°F. retards the action of the developer and is likely to result in underdevelopment, whereas an excessively high temperature may not only produce fog but may soften the emulsion and make it susceptible to damage. When it is impossible to control the temperature within an optimum range by ordinary methods, an electric refrigeration unit should be employed.

Although the processing solutions should be used at a temperature of 68°F., there are occasions when it is necessary to work at some other temperature. Compensation can then be made *within limits* by increasing or decreasing the time of development. When using Kodak Rapid X-ray Developer or Kodak X-ray Developer under such circumstances, Kodak Development Time Indicator (MTS3) (Figure 45) will help in selecting a development time that will produce average contrast and density. Rotation of its dial so that the arrow points to a specific temperature will bring to view the correct development times for Blue Brand Film at the three exhaustion periods (discussed on pages 79-82). It will be seen that for higher temperatures, shorter development times are required, and for lower temperatures, longer times are necessary to produce the same effect.

Normal development for Blue Brand Film should be 3 minutes at 68°F. in fresh solutions made from Kodak Rapid X-ray Developer or Kodak Liquid X-ray Developer and Replenisher; 4½ minutes at 68°F. is required in solution made from Kodak X-ray Developer. No-Screen Film requires 2 minutes' *longer* development in either solution, i.e., 5 minutes and 6 ½ minutes, respectively. For maximum speed and contrast, Blue Brand Film may be developed in Kodak Rapid X-ray Developer or Kodak Liquid X-ray Developer and Replenisher for 5 minutes at 68°F., and No-Screen Film for 7 minutes.

For efficient time-temperature processing, the level of the developer in the tank should be kept at a fairly constant point. The absorption of the developer solution by the dry film after immersion, and the carry-over of the developer to the rinse bath gradually reduces the level of the solution. The amount lost should be restored by adding fresh developer or replenisher. Water should never be added to maintain the level of the developer because the solution

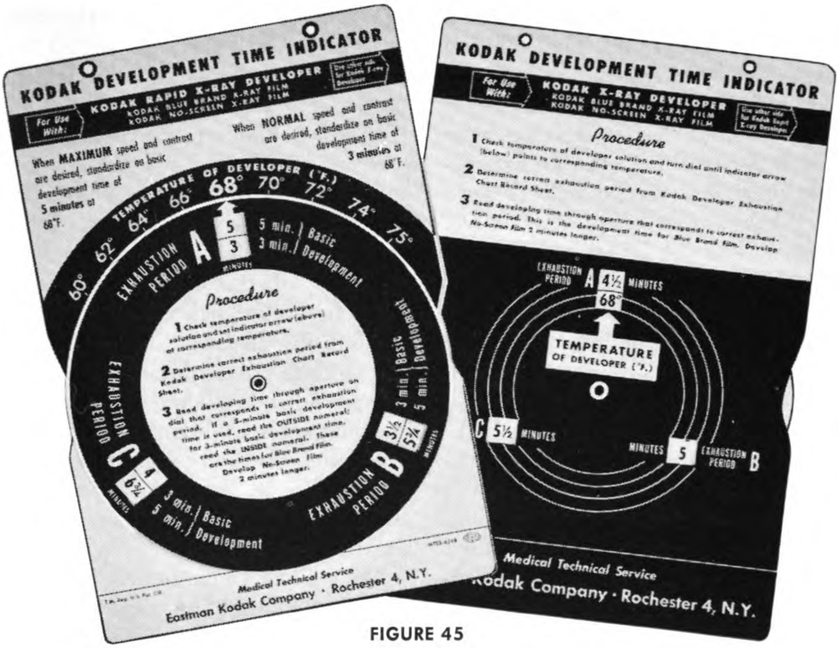

KODAK DEVELOPMENT TIME INDICATOR
For Use With:
KODAK RAPID X-RAY DEVELOPER
KODAK BLUE BRAND X-RAY FILM
KODAK NO-SCREEN X-RAY FILM
When MAXIMUM speed and contrast are desired, standardize on basic development time of 5 minutes at 68°F.
When NORMAL speed and contrast are desired, standardize on basic development time of 3 minutes at 68°F.
TEMPERATURE OF DEVELOPER (°F.)
60° 62° 64° 66° 68° 70° 72° 74° 75°
EXHAUSTION PERIOD A
5 min. 3 min. Basic Development
EXHAUSTION PERIOD B
EXHAUSTION PERIOD C
Procedure
Medical Technical Service
Eastman Kodak Company · Rochester 4, N.Y.
KODAK DEVELOPMENT TIME INDICATOR
For Use With:
KODAK X-RAY DEVELOPER
KODAK BLUE BRAND X-RAY FILM
KODAK NO-SCREEN X-RAY FILM
Procedure
EXHAUSTION PERIOD A 4½ MINUTES
68°
TEMPERATURE OF DEVELOPER (°F.)
C 5½ MINUTES
MINUTES 5 EXHAUSTION PERIOD B
Medical Technical Service
Kodak Company · Rochester 4, N.Y.

FIGURE 45

would become diluted and proper development could not take place.

The importance of a well-functioning developer in the production of good-quality radiographs is well known. Exhausted developer should never be used because a weakened solution causes stain, poor detail, low-density images, and chemical fog. Other factors that shorten the usefulness of the developer are exposure to air and high temperatures, and dilution with water. Developer begins to age as soon as it is mixed—whether it is used or not. For example, if the developer remains uncovered, the developing agents and preservative are slowly oxidized by the air. During development, several chemical reactions take place which tend to exhaust the solution. In use, the developing agents are destroyed by doing useful work in reducing the exposed silver halide crystals of the emulsion to black metallic silver. These reaction products accumulate. And lastly, the bromide and developer oxidation products slow up the speed of the development.

As films are developed, the gradual loss of developer occasioned by the carry-over of films from developer to rinse bath necessitates the adoption of a system for renewing the activity of the developer and maintaining its level in the tank. When this is accomplished by adding fresh developer, it is still necessary to increase the time of development according to the number of films developed, as indicated on an exhaustion chart. After a large number of films has been developed and the exhaustion point reached, prolonged development will not produce a satisfactory radiograph. The solution must then be changed.

For the convenience of users of Kodak Rapid X-ray Developer or Kodak X-ray Developer, an exhaustion chart and record pad (Figure 46) have been made available. Known as Kodak Developer Exhaustion Chart (MTS1), and Record Sheet Pad for Kodak Developer Exhaustion Chart (MTS2), they are obtainable free on request from *Medical Technical Service,* Eastman Kodak Company, Rochester 4, N. Y. The chart is based upon the *area* of film actually developed. A record is easily kept by noting the sizes of the films processed on the pad supplied with each chart, employing symbols to denote various sizes of film processed. Each square represents a film area equivalent to one 14x17-inch film; the symbol employed for this size film is a *diagonal* mark. The 8x10-inch films are represented by *horizontal* marks — three of which are equal to one 14x17-inch film. The 10x12-inch films are represented by *vertical* lines — two of which are equal to a 14x17-inch film. The 4x10-inch films may be represented by dots, six of which are equivalent to the area of one 14x17-inch film. This chart and record pad make it possible for the user to forecast accurately the point where an increase in the time of development (based on the temperature) should occur and when the solution should be discarded. Hence, the use of the chart aids in securing good-quality radiographs at all times.

The "Time-Temperature Exhaustion Data" tables on page 81 represent a summary of the information obtainable with Kodak Developer Exhaustion Chart and Kodak De-

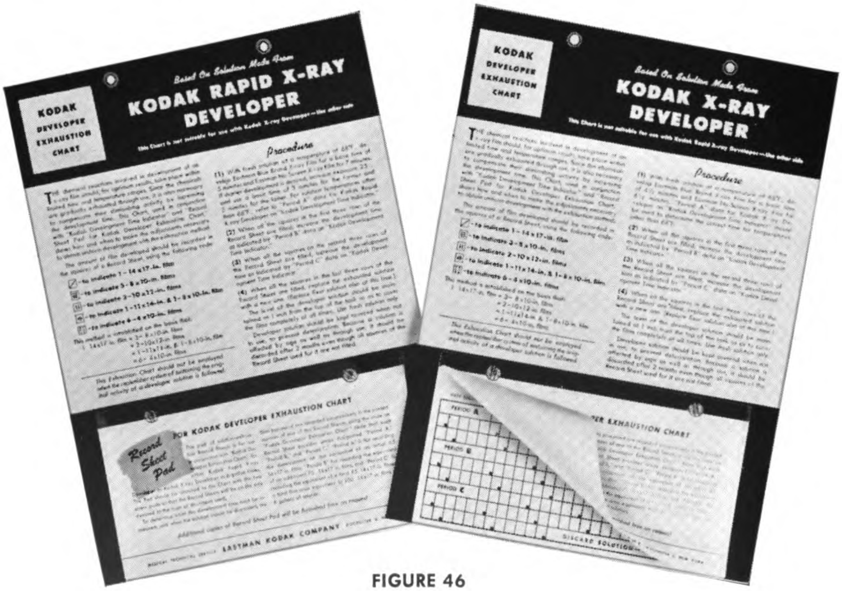

KODAK DEVELOPER EXHAUSTION CHART
Based On Solution Made From
KODAK RAPID X-RAY DEVELOPER
Procedure
FOR KODAK DEVELOPER EXHAUSTION CHART
Record Sheet Pad
EASTMAN KODAK COMPANY
KODAK DEVELOPER EXHAUSTION CHART
Based On Solution Made From
KODAK X-RAY DEVELOPER
Procedure
PERIOD A
PERIOD B
PERIOD C
DISCARD SOLUTION

FIGURE 46

velopment Time Indicator. They indicate the change in time required after specific areas of 14x17-inch films have been developed employing one or the other of two types of developers in 6-gallon quantities. For example, by consulting the upper table for Kodak X-ray Developer,

Time-Temperature Exhaustion Data*

FOR USE WITH KODAK X-RAY DEVELOPER

Temperature of Solution	**BLUE BRAND FILM** Number of 14x17-in. Films Developed Per Period			**NO-SCREEN FILM** Number of 14x17-in. Films Developed Per Period		
	Period A *65 Films*	Period B *70 Films*	Period C† *65 Films*	Period A *65 Films*	Period B *70 Films*	Period C† *65 Films*
60°F.	6¾ min.	7½ min.	8½ min.	8¾ min.	9½ min.	10½ min.
62°F.	6 min.	6½ min.	7½ min.	8 min.	8½ min.	9½ min.
64°F.	5½ min.	6 min.	6¾ min.	7½ min.	8 min.	8¾ min.
66°F.	5 min.	5½ min.	6 min.	7 min.	7½ min.	8 min.
68°F.	4½ min.	5 min.	5½ min.	6½ min.	7 min.	7½ min.
70°F.	4 min.	4½ min.	5 min.	6 min.	6½ min.	7 min.
72°F.	3¾ min.	4 min.	4½ min.	5¾ min.	6 min.	6½ min.
74°F.	3¼ min.	3½ min.	4 min.	5¼ min.	5½ min.	6 min.
75°F.	3 min.	3¼ min.	3¾ min.	5 min.	5¼ min.	5¾ min.

*Based on 6 gallons of solution.

†At end of Period C, replace the exhausted solution with a new one.

Time-Temperature Exhaustion Data*

FOR USE WITH KODAK RAPID X-RAY DEVELOPER†

Temperature of Solution	**BLUE BRAND FILM** Number of 14x17-in. Films Developed Per Period			**NO-SCREEN FILM** Number of 14x17-in. Films Developed Per Period		
	Period A *65 Films*	Period B *70 Films*	Period C‡ *65 Films*	Period A *65 Films*	Period B *70 Films*	Period C‡ *65 Films*
60°F.	5 min.	6 min.	6¾ min.	7 min.	8 min.	8¾ min.
62°F.	4½ min.	5 min.	6½ min.	6½ min.	7 min.	8½ min.
64°F.	4 min.	4½ min.	5½ min.	6 min.	6½ min.	7½ min.
66°F.	3½ min.	4 min.	4½ min.	5½ min.	6 min.	6½ min.
68°F.	3 min.	3½ min.	4 min.	5 min.	5½ min.	6 min.
70°F.	2½ min.	3 min.	3½ min.	4½ min.	5 min.	5½ min.
72°F.	2¼ min.	2¾ min.	3 min.	4¼ min.	4¾ min.	5 min.
74°F.	2 min.	2½ min.	2¾ min.	4 min.	4½ min.	4¾ min.
75°F.	1¾ min.	2¼ min.	2½ min.	3¾ min.	4¼ min.	4½ min.

*Based on 6 gallons of solution.

†This table is not to be used when the *replenisher* method of processing is employed.

‡At end of Period C, replace the exhausted solution with a new one.

it may be seen that for Blue Brand Film, during Period "A," development is 4½ minutes at 68°F. During Period "B," the time increases to 5 minutes. During Period "C," the time increases to 5½ minutes. It should be noted that at the end of Period "C," all solutions are discarded and fresh ones made.

Replenisher System Under the discussion of time-temperature *exhaustion* processing, it was pointed out that new developer must be added to the tank from time to time to replace that absorbed by dry films and to keep the level constant. In this method, the development time is increased to compensate for exhaustion of the solution. In the *replenisher method*, through the use of a solution of greater activity, the developing time can be kept constant throughout its life.

When Kodak Liquid X-ray Developer and Replenisher is used, the replenisher may be prepared from it according to the directions on the bottle. If Kodak Rapid X-ray Developer is used, Kodak Rapid X-ray Replenisher should be obtained for replenishment. If Kodak X-ray Developer is chosen, its activity should be maintained with Kodak X-ray Replenisher.

With the replenisher method, films should be removed from the developer quickly, and the excess solution should *not* be allowed to drain back into the tank. Normally, this procedure will carry out about the proper amount of solution. Approximately one gallon of replenisher should be added for every forty 14x17-inch films, or their equivalent area. If sufficient solution has not been removed by the carry-over, the films have been allowed to drain too much, and it may be necessary to dip some developer from the tank in order to add the proper amount of replenisher. When adding replenisher solution, it is always good practice to read the label on the container, to make certain that the correct volume is being used during the life of the developer.

Obviously, it is not practical to continue replenishment indefinitely, and the solution should be discarded when the replenisher used is approximately equal to four times the original quantity of developer. It is also recommended that the solution be discarded at the end of a three-month period, even though the addition of this amount of replenisher has not been required.

A special development time indicator (Figure 47) is available for use with the replenisher system. It is available free upon application to your Medical Division representative or to *Medical Technical Service*, Eastman Kodak Company, Rochester 4, N. Y. Ask for Replenisher System Kodak Development Time Indicator (MTS6).

Rinsing

After a film has been developed, it retains a large amount of developer solution, so it must then be immersed in clean, circulating water for at least 20 seconds in the case of Blue Brand Film, and 45 seconds for No-Screen Film. If films are transferred from the developer to the fixing bath without thorough rinsing, the alkali of the developer retained by the film will neutralize the acid of the fixer. This causes early deterioration of the bath and its usefulness is greatly impaired; the hardening action is also affected and stains are likely to be produced on the radiograph.

Fixation

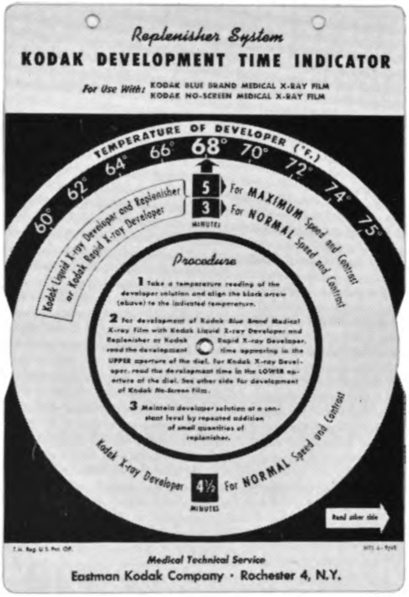
When an exposed x-ray film is developed, only those silver halide crystals which were exposed are converted into the permanent silver image. The unexposed crystals remain in the emulsion, unaffected by the developer. To complete the processing procedure, the developed film must be cleared of these crystals and the emulsion hardened. This process is known as fixation.

The constituents of a fixer and their individual functions follow.

1. The *clearing agent* dissolves the *unexposed* silver halide crystals remaining in the emulsion after development. The usual chemical employed for this purpose is *sodium thiosulfate* — commonly known as "hypo." This function serves to "clear" the film so that the black silver image produced by the developer becomes discernible. When the film is improperly cleared, the remaining unexposed crystals darken on exposure to light and obscure the radiographic image.

2. The *preservative* prevents decomposition of the sodium thiosulfate and resultant precipitation of sulfur in the presence of acid at normal temperatures, and assists the sodium thiosulfate in clearing the film. It also prevents the residual developer carried over in the film from oxidizing and discoloring the fixing bath. The chemical used is *sodium sulfite*.

3. The *hardening* agent shrinks, **tans, or hardens the gelatin emulsion** so as to prevent excessive swelling or softening and thus to facilitate washing and drying. The most effective salt for this purpose is *potassium alum* (white alum).


Replenisher System
KODAK DEVELOPMENT TIME INDICATOR
For Use With: KODAK BLUE BRAND MEDICAL X-RAY FILM
KODAK NO-SCREEN MEDICAL X-RAY FILM
TEMPERATURE OF DEVELOPER (°F.)
60° 62° 64° 66° 68° 70° 72° 74° 75°
Kodak Liquid X-ray Developer and Replenisher or Kodak Rapid X-ray Developer
5 For MAXIMUM Speed and Contrast
3 For NORMAL Speed and Contrast
MINUTES
Procedure
Kodak X-ray Developer
4½ For NORMAL Speed and Contrast
MINUTES
Read other side
T.M. Reg. U.S. Pat. Off.
Medical Technical Service
Eastman Kodak Company · Rochester 4, N.Y.

1 Take a temperature reading of the developer solution and align the black arrow (above) to the indicated temperature.

2 For development of Kodak Blue Brand Medical X-ray Film with Kodak Liquid X-ray Developer and Replenisher or Kodak Rapid X-ray Developer, read the development time appearing in the UPPER aperture of the dial. For Kodak X-ray Developer, read the development time in the LOWER aperture of the dial. See other side for development of Kodak No-Screen Film.

3 Maintain developer solution at a constant level by repeated addition of small quantities of replenisher.

FIGURE 47

4. The *acidifier* provides the necessary acid medium and makes possible the correct action of the clearing agent, preservative, and hardener on the film. It also serves to neutralize the alkaline developer that is carried over by the film. The chemical employed for this purpose is usually *acetic acid*.

Packaged chemicals in powder form are available for making fixing solutions. Fixer also may be obtained in liquid form. In either case, the only necessary step to make a well-functioning bath is to mix them in the required amount of water. The powdered chemical is Kodak X-ray Fixer which when in solution provides short clearing and hardening times and has long life. Kodak Liquid X-ray Fixer and Replenisher provides an easy and convenient way to prepare a fixing bath. Its advantage is that its clearing time is less than that of the solution made from the powdered chemical.

After rinsing, the radiograph is placed in the fixing bath and moved up and down (agitated) several times so that every part of the film surface is bathed. Films should be spaced so that they do not touch each other. White light should not be turned on in the darkroom until 2 to 3 minutes have elapsed, otherwise the film will be fogged. This period of time will suffice for the acid to stop effectively any developer activity in the film.

As in the case of the developer, the activity of the fixing bath is influenced by the temperature and its freshness. The temperature should be maintained at 68°F. in order to preclude abnormal swelling and assure a minimum drying time. Under normal conditions of temperature and activity, tank fixation for x-ray film usually requires twice the length of the clearing time.

The usefulness of the bath comes to an end when it has lost its acidity or when a protracted time is required to remove the unexposed silver salts from the film. The use of an exhausted fixing bath should always be avoided, for it often results in abnormal swelling due to deficient hardening action; drying is prolonged, too, and reticulation or sloughing of the emulsion may take place. In addition, neutralization of the acid in the fixing bath invariably causes certain types of stain to appear on the radiographs. An exhausted bath should be replaced with a new one.

During the summer months and throughout the year in localities where exceptionally high temperatures prevail, as in the tropics, the fixing bath should be changed *twice* during the life of the developer. As a routine measure, the volume of fixer should always be twice that of the developer. When the developer is changed, the fixer is changed. These practices assure maximum hardening of the emulsion and relative freedom from hot-weather troubles.

Any discussion of fixing baths is incomplete without some mention of their secondary characteristics which may pose problems if the solutions are improperly handled.

Sludging Excess developer carried over into the fixer solution tends to precipitate some of the hardening agent. The result may be a white sludge in the solution, or a white scum on the films. This sludging may be prevented if films are thoroughly rinsed in flowing water between development and fixation. The films should then be adequately drained so that only a minimum of developer-contaminated rinse water is transferred to the fixer.

Streakiness Uneven density or streakiness in uniformly exposed areas also often results if films are not rinsed before fixation and agitated during fixation. This is due to the fact that one or two minutes may elapse before the alkali in the developer carried over by the films is neutralized by the acid in the fixer solution. This is especially the case with No-Screen Film. During this time, development of the film may continue unevenly in the fixer solution, resulting in streaks. The importance of adequate rinsing cannot be too strongly emphasized.

Opalescence Occasionally, a film viewed immediately after fixation in a fresh solution made from Kodak X-ray Fixer appears opalescent, which may cause the observer some concern. The condition, however, is transient, disappearing when the film is washed and dried. It is caused by the reaction of the gelatin of the emulsion to the high concentration of sodium thiosulfate in the fixer. A fixer solution prepared from Kodak Liquid X-ray Fixer and Replenisher which contains ammonium thiosulfate is much less concentrated than that prepared from the powdered chemicals (although it will do more useful work) and has little or no tendency to produce opalescence in the radiograph.

Staining of Clothing As any fixer solution continues in use, the concentration of silver salts in solution increases. One result of this accumulation of silver, especially in solutions containing ammonium thiosulfate, is that it stains fabrics, the spots becoming visible only *after laundering*. Information on removal of stains is given on page 116.

Washing

Washing of radiographs must be regarded as a chemical operation, the object of which is to remove residual processing chemicals from the radiograph. Proper washing ensures permanence of radiographs as records. If these chemicals are not removed, the image will discolor and fade and the entire film will deteriorate. X-ray films should be washed in running water so circulated that the entire emulsion area will receive frequent changes. In tank processing, the bar of the hanger and the top clips should always be completely covered by the water (Figure 48, page 86).

The time required for adequate washing depends principally upon the type of x-ray film to be washed and the rate at which the water flows through the tank. The washing time should be measured from the immersion of the *last* film in the wash water, since washed and partly washed films absorb fixing bath chemicals from contaminated water as well as release them in fresh water. If the hourly flow is 4 times the capacity of the tank, 30 minutes is required for washing Blue Brand Film, and 40 to 60 minutes for washing No-Screen Film. When the hourly flow is 8 to 10 times the capacity of the tank, 15 to 20 minutes is sufficient for Blue Brand Film and 20 to 30 minutes for No-Screen Film. Shorter intervals should not be used no matter how frequently the water in the tank is changed; and, if the flow through the tank is very slow, the films should remain in the water even longer than the first-specified periods. (Special instructions for tray washing are given on pages 88 and 89.)

Under warm weather conditions the flow of water should be such that films will be washed in the shortest possible time, since the gelatin emulsion has a tendency to soften with prolonged washing. The temperature of the wash water preferably should not exceed 75°F. However, if temperatures above 75°F. are employed, special precautions should be taken

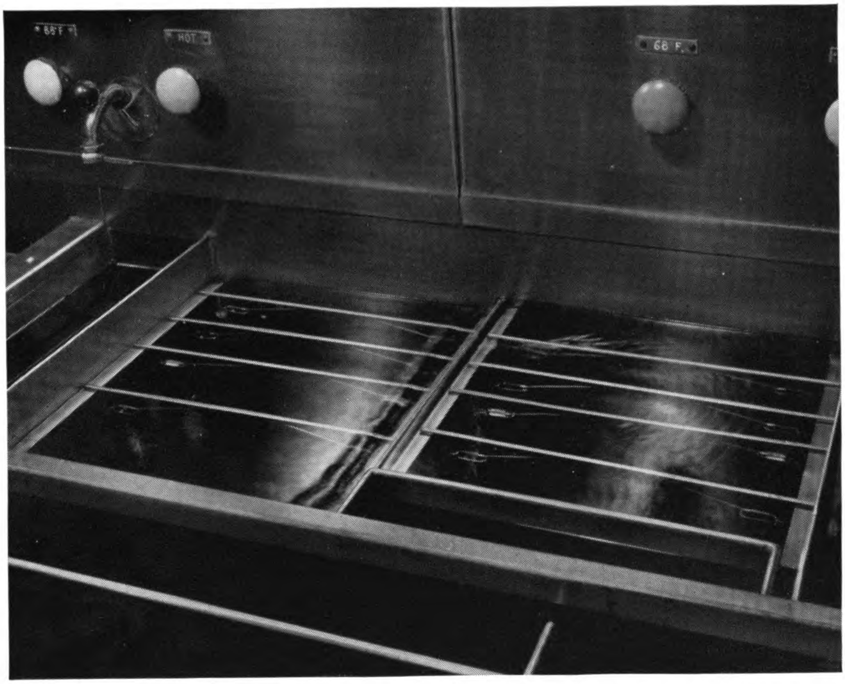


FIGURE 48—Water should flow over the tops of hangers in the washing compartment.

in processing the films. For further information, see pages 89 and 90.

Drying

Drying is the simplest step in processing and contributes to the excellence of the radiograph if properly handled. Much surface water can be prevented from clinging to radiographs by lifting them slowly from the wash water. Immersion of radiographs, following washing, in a solution containing ½ ounce of Kodak Photo-Flo Solution to a gallon of water will facilitate drying and prevent the formation of water marks.

If only a small quantity of radiographs is processed daily, a convenient rack may be made on which to suspend the hangers while the films are drying. Films should not be hung one above the other because water drops may fall on the lowermost films and produce marks. When large quantities of films are to be dried, proper drying cabinets should be constructed or purchased and equipped with fans and heater units. They should be vented to the outside air to prevent excessive local humidity.

Heat should be used cautiously when drying films in hot, humid weather because the water-laden gelatin emulsion may soften and ruin the radiograph. Under these conditions, it is safest to use only the dryer fan. Drying should preferably be done in a dry room free from dust and strong drafts. Too rapid drying is apt to cause wrinkling, and over-heating should be guarded against.

Summary of Tank Processing

The steps employed in tank processing of x-ray film are as follows:

1. Check the temperature of the solution and adjust temperature to 68°F. before development; stir the developer and fixer solutions with *separate* paddles to obtain a uniform temperature.

2. Remove film from its holder and clip into a developing hanger; set interval timer so it will ring at end of desired period of development. See tables on page 81.

3. Immerse film smoothly in the developer solution and start timer; agitate film hanger by raising and lowering it several times to break up residual air bells and permit solution to bathe both surfaces of the film. Repeat agitation several times during course of development. Mark the size of film developed on the Exhaustion Chart Record Sheet. When the alarm bell rings, remove hanger from developer.

4. Place the film in circulating rinse water and agitate hanger.

5. After rinsing, immerse the film in the fixer solution and agitate until fixer has thoroughly bathed both film surfaces. Do not expose to white light until the film has cleared.

6. Upon completion of fixation, remove film to the washing compartment. Let it remain until it is completely washed in circulating water.

7. After washing, drain the film in its hanger and hang up to dry or place in a dryer that supplies circulating, clean, dry air.

8. Remove the dry radiograph from the hanger by *opening* the clips which release the hanger's grip on the corners. Do not pull film from clips since clips may be broken or portions of film remain to clog them later when another film is to be processed. The corners of the radiograph should be rounded and the radiograph placed in its proper envelope.

TRAY PROCESSING

When circumstances are such that a tank installation is not practical, or that the number of films processed each day does not warrant a tank system, satisfactory results may be obtained by utilizing trays, if the necessary care is exercised. This method is not as efficient as the tank system.

At least four heavy, durable, white-enameled trays are essential. They should be of adequate size to accommodate the largest film that is used. Kodak Enameled Trays are made especially for processing, and there is a choice of sizes for every requirement. One tray is used for developer solution, another for rinse water, a third for fixer solution, and a fourth for wash water. The tray for washing should be fitted with a Kodak Automatic Tray Siphon (Figure 49, page 88) so the water will be kept in constant circulation.

A quantity of solution should be mixed at regular intervals and kept, preferably, in brown bottles. Then a sufficient amount to cover the film to a depth of at least 1 inch is poured into the proper trays just before processing; during use the temperature of the solutions should be 68°F.

The procedure differs in some respects from that used in tank processing. It is advisable to develop only one film at a time and care must be exercised so that the softened emulsion may not be scratched during development and the film does not stick to the bottom of the tray. The method requires somewhat less time than tank processing because of the need for constant agitation of solutions in trays. Assuming that the solutions are prepared and at a temperature of 68°F., the steps are as follows:

1. On removing the film from the cassette or exposure holder, attach a Kodak Dental X-ray Film Clip to one corner to facilitate handling. Then immerse the film in the developer solution by a quick sliding motion so that it is completely covered. Unduly slow and uneven immersion will result in a dark line on the radiograph where the developer paused.

2. Start the timer for the proper interval as indicated by the temperature and activity of the solutions. Because of the more-or-less continuous agitation afforded by the procedure, it requires 20 per cent less development time than the tank system.

During development, the film must be moved about frequently so that the underside does not adhere to the tray and thereby retard the action of the developer on the emulsion. It is also advisable to turn the film over several times during development. The tray must be rocked to provide continuous redistribution of the solution over both surfaces of the film. This agitation can be accomplished by raising and lowering alternate sides of the tray, and must continue throughout the processing period.

3. Rinse the film in fresh water, 20 seconds for Blue Brand Film; 45 seconds for No-Screen Film.

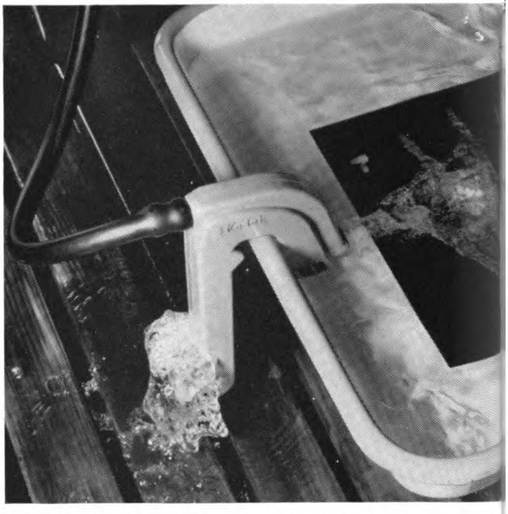


FIGURE 49—Kodak Automatic Tray Siphon used for washing radiographs in a tray.

4. Then transfer it to the fixer solution, allowing 15 minutes for Blue Brand Film, and 20 to 30 minutes for No-Screen Film. When the film is first placed in the tray and at intervals during fixation, the solution should be agitated by the method described above. The film must not be allowed to rest on the bottom.

5. After fixation, the film should be washed in running water for not less than 20 to 30 minutes; the rate of flow should be rapid enough to replace the water in the tray at least 8 to 10 times an hour. If several films are developed in succession, the washing time must be calculated from the time the last film is placed in the wash water.

The solutions should not be left in the trays after processing is completed, because oxidation of the developer solution shortens its useful life. Furthermore, dust and other foreign matter will collect in the uncovered trays. For these reasons, the developer and fixer solutions should be returned to their respective bottles promptly after use or discarded.

HIGH-TEMPERATURE PROCESSING

If it is not feasible to cool the solutions and wash water to 68°F., a number of general precautions may be exercised to lessen the difficulties of processing x-ray film at higher temperatures. For temperatures from 68° to 75°F., the development time should be shortened as determined with the Development Time Indicator; the fixer solution should be renewed frequently; the films should be fixed for fully 15 minutes to ensure maximum hardening; and the washing time should be limited to 15 minutes. A good practice is to use a fixing bath of twice the volume of the developer and to change the fixer when the developer is changed. The short development, thorough fixation, and minimum washing all help to prevent excessive softening and swelling of the gelatin.

For processing at temperatures above 75°F., further precautions may be taken. The use of Kodak X-ray Developer is preferable, while a solution made from Kodak X-ray Fixer is essential. It is not generally possible to work with solutions at temperatures above 95°F. owing to danger of reticulation and blisters. The recommended processing times for development, hardening, and fixing of Blue Brand and No-Screen Films are indicated in the table, "High-Temperature Processing Times," page 90.

Between development and fixation, the film should be rinsed in a hardening bath made according to the formula given below. The film should be agitated when first immersed and left in it for about 3 minutes.

KODAK HARDENING BATH SB-4

	Avoirdupois	Metric
Water..........	1 gal.†	1.0 liter†
Kodak Potassium Chrome Alum....	4 oz.	30.0 gm.
Kodak Sodium Sulfate desiccated*	8 oz.	60.0 gm.

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*If crystalline sodium sulfate is used in place of the desiccated, increase the quantity in the above formula by 2¼.

†The same proportions of ingredients should be used for making larger or smaller quantities of solutions.

When the temperature of the processing solutions is 90°F. or above, sodium sulfate should be added to the developer solutions as indicated in the table "Developer, Hardener, and Fixer Solutions for High-Temperature Processing" (page 90). When the temperature is 95°F., sodium sulfate should be added to the hardening bath also. Once the sodium sulfate has been added, the bath should not be allowed to cool; if its temperature falls 5 or 10 degrees, the sodium sulfate may crystallize.

The hardening bath should be mixed fresh every 24 hours because, when partially used, the bath loses its hardening properties rapidly.

Both Blue Brand and No-Screen Films should remain in the hardening bath for 3 minutes; during the first minute they should be agitated frequently to prevent the formation of a precipitate on the film surface. Next, the films should be transferred to the fixing solution. In order to minimize exposure to the air, the films must be transferred quickly from one solution to the other.

In washing the films the flow of water should be sufficient to permit washing for a period not exceeding 10 minutes, since prolonged washing may cause the gelatin in the emulsion to swell excessively. In a single wash tank, the hourly flow of water should be at least 15 times the volume of the tank. In the two-compartment cascade washing system, the flow of water should be at least 8 times the volume of one compartment.

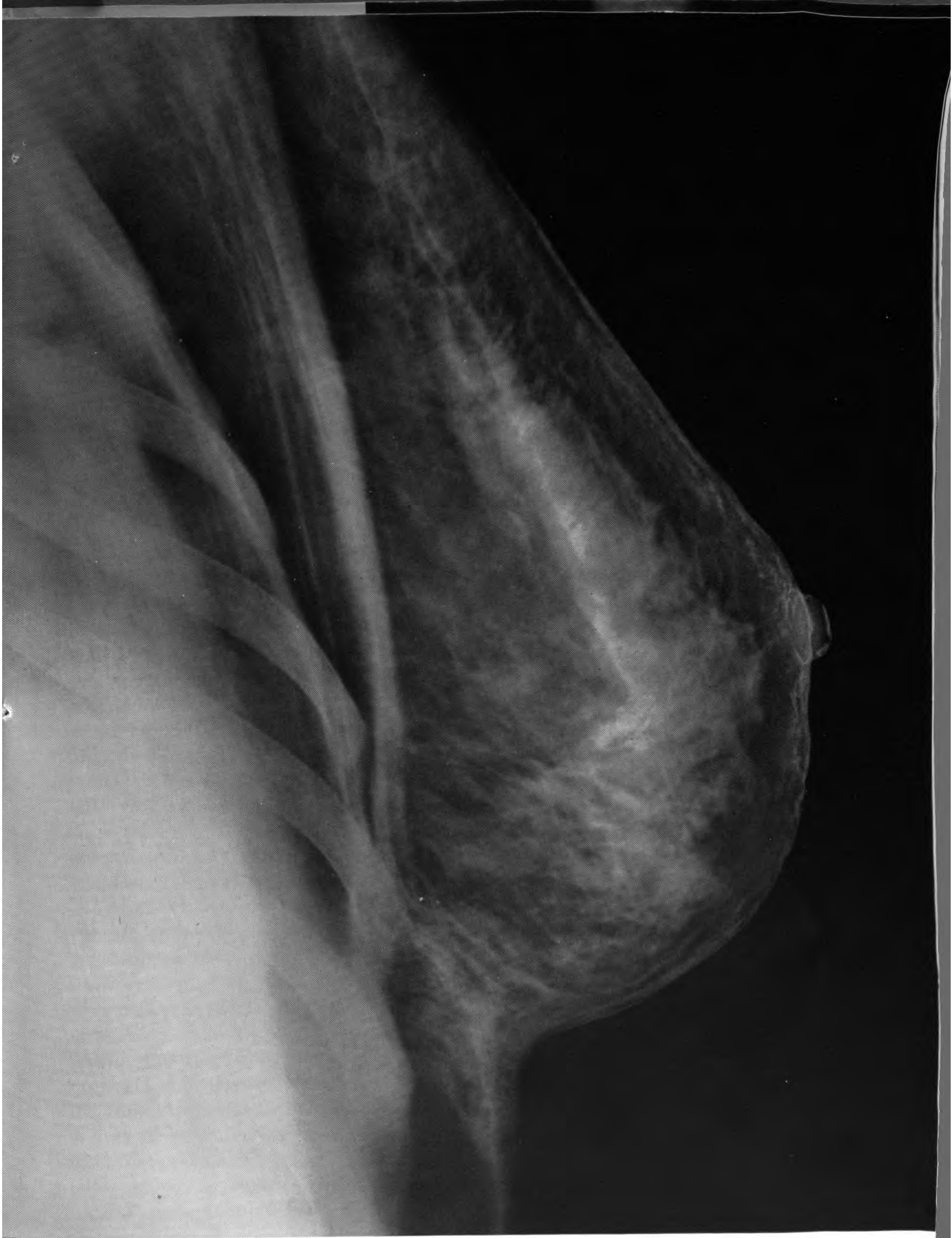
High-Temperature Processing Times

TEMPERATURE	FILM	DEVELOPMENT	HARDENING	FIXATION
		KODAK X-RAY DEVELOPER	KODAK HARDENING BATH SB-4	KODAK X-RAY FIXER
80°F.	Blue Brand	2½ min.	3 min.	10 min.
	No-Screen	4 min.	3 min.	15 min.
90°F.	Blue Brand	2½ min.	3 min.	10 min.
	No-Screen	4 min.	3 min.	15 min.
95°F.	Blue Brand	2¼ min.	3 min.	10 min.
	No-Screen	3½ min.	3 min.	15 min.

Developer, Hardener, and Fixer Solutions for High-Temperature Processing

TEMPERATURE	DEVELOPER	HARDENER	FIXER
	KODAK X-RAY DEVELOPER	KODAK HARDENING BATH SB-4	KODAK X-RAY FIXER
80°F.	Standard solution	Standard solution	Standard solution
90°F.	Modified solution*	Standard solution	Standard solution
95°F.	Modified solution†	Modified solution‡	Standard solution

*Add 10 oz. of sodium sulfate (desiccated) per gallon of developer solution.
†Add 20 oz. of sodium sulfate (desiccated) per gallon of developer solution.
‡Add 7 oz. of sodium sulfate (desiccated) per gallon of hardener solution.



Radiograph of an insufflated mammary gland.

C

Viewing and Filing Radiographs

• The purpose of every radiograph is, in the final analysis, to furnish facts on which the radiologist can base his interpretation. Since this information can be ascertained only by a careful study of the image, the best facilities for examination of the image should be provided.

In selecting viewing equipment, therefore, it should be kept in mind that the interpretive value of every radiograph will be materially affected by the quality and the intensity of the illumination. The inherent latitude of x-ray film makes it possible to obtain satisfactory radiographs of a given subject in several density ranges. This latitude and the fact that the human eye has the ability to discriminate between small density differences over a considerable brightness range are both taken into account in the design of modern viewing equipment.

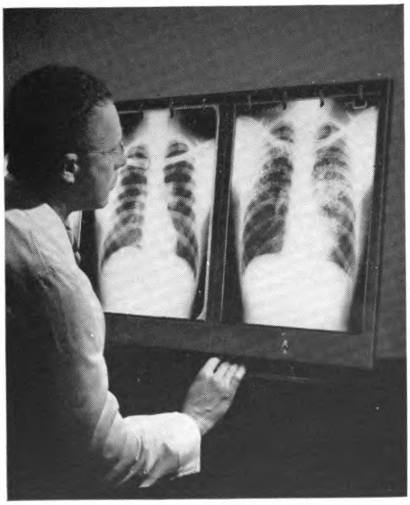


FIGURE 50

To be satisfactory for use in viewing radiographs, an illuminator must fulfill two requirements: it must provide light of an intensity that will illuminate the average-density areas of the radiographs to best advantage, free from glare; and it must diffuse the light evenly over the entire viewing area. These requisites are adequately provided by the bluish-white light from illuminators fitted with tubular fluorescent lamps.

The Kodak Coldlight X-ray Illuminator, Model A (Figure 50), ably meets the conditions for proper viewing, and its design is such that it promotes efficiency, economy, and comfort in the viewing room. As the name implies, this illuminator provides "cold" light so that radiographs are not subjected to heat, and there is no eye discomfort during close inspection or long periods of interpretation. Two 15-watt, T-8 Daylight Fluorescent Lamps comprise the light source; their current consumption is very low. The viewing area is 14x17 inches, with rounded corners; the untinted flashed opal glass is supported at a slightly backward angle and is readily removable. At the top

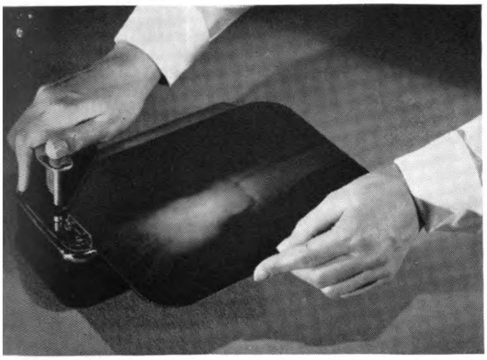


FIGURE 51—Corners of radiographs are rounded with Kodak X-ray Corner Cutter.

of the frame are 4 spring-clip fingers, to retain dry radiographs, and 2 bracket arms, to support film hangers containing wet radiographs. The illuminator measures only 5 inches in depth, and, therefore, is ideal for recessing in a wall. When used on a desk or shelf, it occupies a small amount of space and will not skid out of position. In offices, x-ray departments, or operating rooms a row or bank of several Kodak Coldlight X-ray Illuminators enables a series of radiographs, as of the gastrointestinal tract, to be viewed at one time.

The sensitivity of the eye to contrast is practically independent of the color of the illumination. Adequate intensity of illumination, of whatever color, is the primary requisite. The majority of radiologists prefer blue-white light that simulates daylight, but, as a matter of fact, in employing illumination of the same degree of brightness, preference for light of a certain color is more likely to be based on personal taste than on any demonstrable advantage or disadvantage. If radiographic viewing conditions indicate the need for still brighter illumination than that provided by fluorescent lamps, high-intensity illuminators built for this purpose are commercially available.

A fact worth keeping in mind is that the eyes always require a few minutes to accommodate themselves to any marked change in light intensity. Therefore, in order not to subject them to unnecessary extremes during the interpretation of radiographs, subdued general illumination should be provided in the viewing room itself. Subdued lighting is definitely preferable to bright lighting or no lighting at all since it more closely approaches the degree of illumination transmitted through radiographs on the viewing equipment.

Filing Radiographs In preparing radiographs for viewing and interpretation, the elimination of the sharp and punctured corners is most desirable. This can conveniently be done with the Kodak X-ray Corner Cutter (Figure 51). It will enhance the appearance of the radiograph, preclude its scratching others with which it may come in contact, facilitate its insertion into an envelope, and conserve filing space. The operation is simple — all that is necessary is to place the radiograph on the top of the cutter; then a slight pressure on the plunger will neatly round the corner by clipping off a fixed area.

As soon as the corners have been trimmed, the radiograph should be placed in a heavy manila envelope of proper size, and all essential identification data should be written legibly in the space provided on the face of the envelope. It can be filed, preferably in a steel cabinet, immediately after interpretation.

Stereoradiography

• Objects viewed with a normal pair of eyes appear in their true perspective and in correct spatial relation to each other largely because of man's natural stereoscopic vision; each eye receives a slightly different view of an object and the two images are combined by the brain to give the impression of three dimensions.

A single radiographic image does not possess perspective. Therefore, it cannot give the impression of depth, or indicate clearly the relative positions of various parts within an object along the direction of vision. To produce radiographs that can give a true stereoscopic effect, two slightly different views must be obtained, corresponding to different images seen by the two eyes in stereoscopic vision. This is done by making *two* radiographs from *two* positions of the x-ray tube, separated by the normal interpupillary distance (about $2\frac{9}{16}$ inches). Such radiographs are ordinarily termed *stereoradiographs*.

The value of stereoradiography cannot be overestimated. It presents

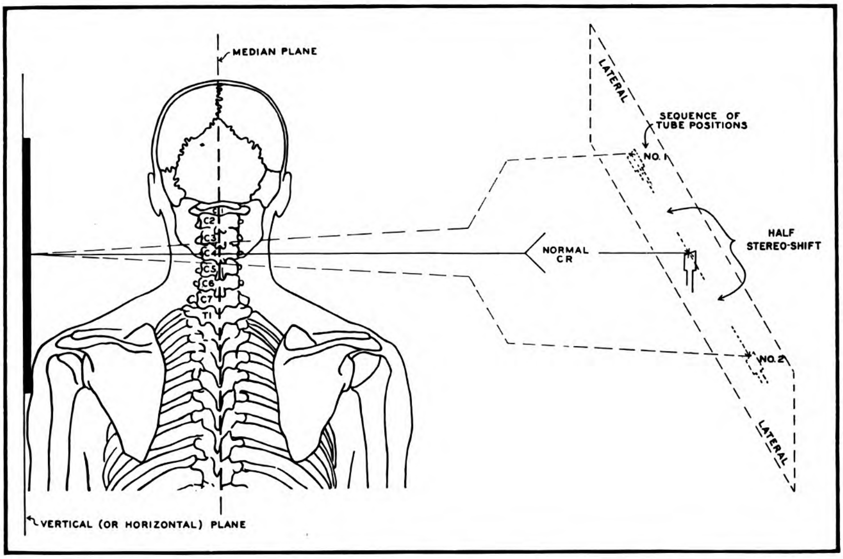


FIGURE 52—Diagram of typical series of stereoradiographic shifts employed in lateral radiography of the cervical vertebrae.

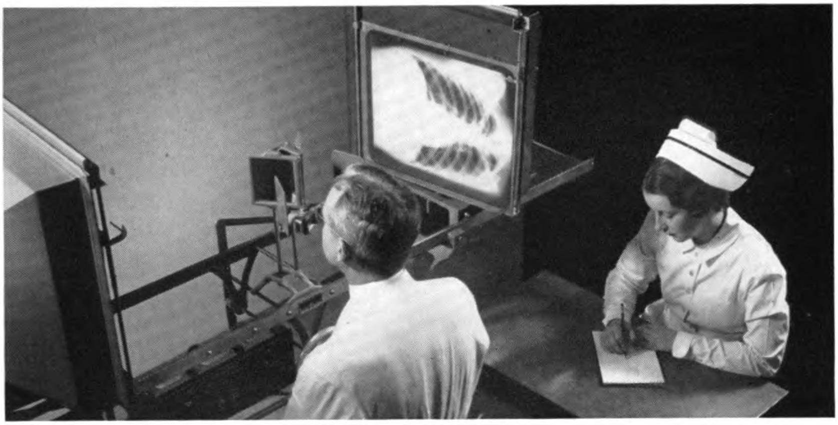


FIGURE 53—Viewing stereoradiograph in a Wheatstone stereoscope.

a clearer visual impression of the relation between the various structures within the body; and, in addition, hairline detail appears more definite than in a single radiographic image. The method is especially advantageous wherever there is an abundance of superimposed structures.

Making Stereoradiographs In making a pair of stereoradiographs, the body remains in exactly the same position for both views. In the interval between the two exposures, the x-ray tube is shifted a suitable distance, dependent upon the focus-film distance employed, in a direction parallel to the film (Figure 52). After the first exposure, the first film is replaced by another film, in the same position. The two radiographs must be exposed and processed alike and should differ in appearance only insofar as the two positions of the x-ray tube produced a difference in the projected images.

In a rigorous application of the theory of x-ray stereoscopy, the shift of the x-ray tube should equal the interpupillary distance of the observer (normally $2\frac{9}{16}$ inches) while the focus-film distance should equal the eye-film distance used in viewing the radiographs in the stereoscope. In practice, as will be explained later, other factors necessitate deviations from these conditions — deviations that are permissible if the magnitude of the tube shift bears the proper relation to the focus-film distance.

In stereoradiography of body parts that may be kept immobilized, the shifts of the tube and film may be performed manually by the radiographer. In stereoradiography of the chest, the patient's breath must be held during the whole interval occupied by the two exposures. Consequently, the tube shifts must occur very rapidly. This is done automatically by means of switches actuated at the control stand. Through a system of interconnected switches, the whole sequence of the two exposures and the intervening shifts can be accomplished by repeating the pressure on a single button.

Viewing Stereoradiographs Stereoradiographs are viewed in a Wheat-

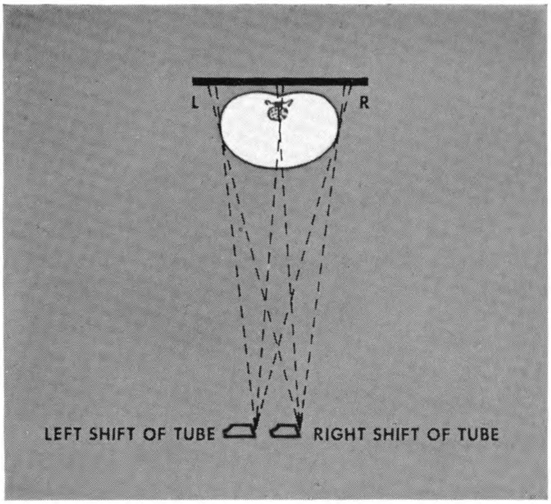


FIGURE 54—Diagram illustrating sequence of tube positions in stereoradiography.

stone type of stereoscope (Figure 53, page 95), a device in which two plane mirrors or two prisms, set at a right angle to each other midway between two facing illuminators, present the reflected images of the stereoradiographs. Each eye sees only one image, but, as in ordinary vision, the brain fuses the two images into one in which the various parts stand out in striking relief in their true perspective and in their correct spatial relation, i.e., depth perspective.

In placing the stereoradiographs in the stereoscope, it is a great convenience to be able to arrange them in their correct positions quickly and easily, without trying several positions before the right one is found. There is but one correct method of placing the stereoradiographs in the stereoscope. If it is not followed, distorted stereoscopic images will occur and distances and spatial relationships in the subject will not be viewed in their true proportions.

The radiograph exposed in the *right*-shift position of the x-ray tube is viewed by the *right* eye, and the one exposed in the *left*-shift position is viewed by the *left* eye. In fact, the conditions of viewing the radiographs should be exactly analogous to the conditions under which they were exposed; the two eyes take the place of the two positions of the focal spot of the x-ray tube, and the radiographs, as reflected in the mirrors, occupy the same position with respect to the eyes as did the films with respect to the tube during the exposures.

When each exposure is made, x-rays emerge from the focal spot of the x-ray tube and pass through the patient to the film (Figure 54). Then, when the two radiographs are properly mounted in the stereoscope, the light rays from the illuminators pass through them and are reflected into the corresponding eyes, reproducing in reverse direction the paths followed by the x-rays in the exposures (Figure 55). Thus, there is exact correspondence in geometric conditions of exposing the films and viewing the radiographs. The observer at the stereoscope sees the image of the body part just as the x-ray tube "saw" the actual part. The stereoscopic image seems to lie between the illuminator and the observer.

Since the mirrors of the Wheatstone-type stereoscope *reverse* the image from right to left, the radiographs must be reversed from right to left when they are placed on the illuminators, so that the tube side of the images will be reflected in the mirrors and identification data can be read correctly.

Identification of the radiographs with respect to the right and left tube-positions frequently may be accomplished by observing the position of the images of a structure or of lead letters and numbers in relation to the edges of the radiographs. Another method is the use of a definite marker; a convenient device for this purpose may be made by mounting a cross of fuse wire on the face of the cassette-changer near one corner, and placing a lead shot a centimeter or so above the wire, in the crest of a small mound of plastic wood. The relative locations of the images of the shot and wire cross in the two radiographs will readily indicate the position that the tube occupied when the exposure was made for each.

Stereoradiographs made with the horizontal tube-shift naturally are viewed in the upright position, while those made with the vertical shift are viewed as though the subject were on its left side. The following procedure should be employed in placing the films in the Wheatstone stereoscope:

1. Superimpose the two stereoscopic radiographs with the tube side away from the observer, holding them so that the direction of the tube shift is horizontal.

2. The film with the image displaced farther to the left is placed in the left illuminator and that with the image displaced farther to the right

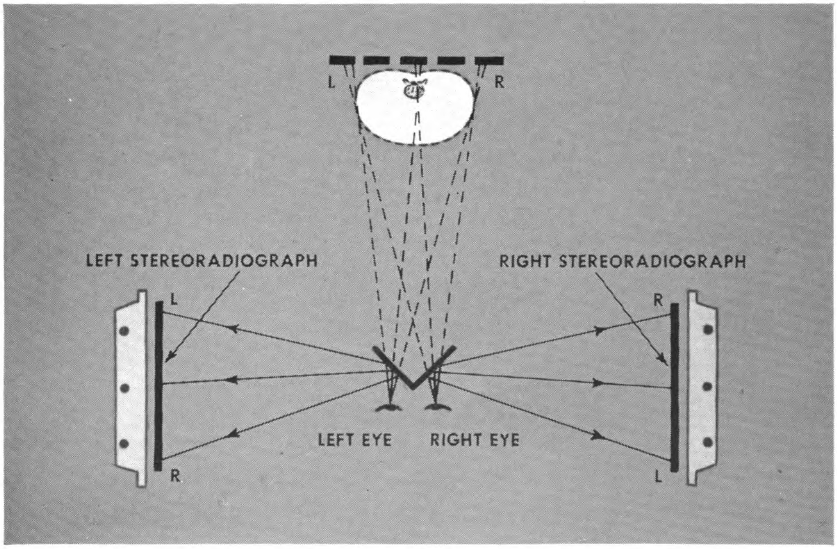


FIGURE 55—Diagram showing position of stereoradiographs in stereoscope in relation to observer's eyes.

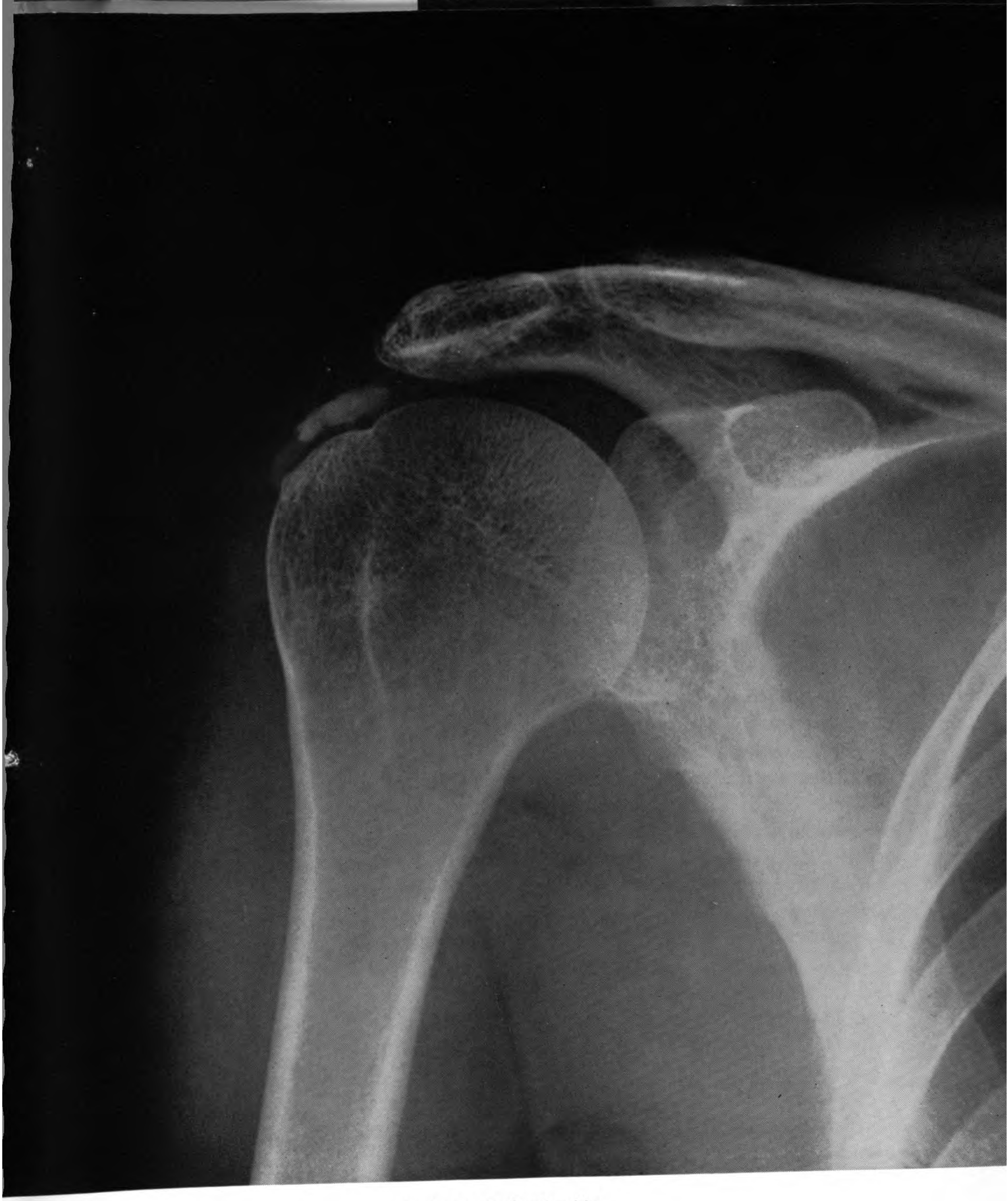
is placed in the right illuminator. The tube sides of the films should face the illuminators.

3. While examining the film through the mirrors, the latter are adjusted to bring the two views into fusion. The two proper adjustments of the mirrors are a horizontal shift toward or away from the observer and a slight lateral tilt to the left or right. Some Wheatstone stereoscopes permit a change in the angle between the two mirrors. This is incorrect. This angle should be maintained at 90 degrees; otherwise, distortion of the stereoscopic image or even difficulty in fusing the views will occur.

In the case of radiographs exposed at long focus-film distances, a rigorous application of the correct conditions for viewing stereoradiographs would require that the eye-film distance be equal to the focus-film distance used in making the exposures. Such long viewing distances are impractical with the usual Wheatstone stereoscope, and, furthermore, would make it difficult to see the finer details in the images. However, by employment of the appropriate stereoscopic tube-shifts at the longer focus-film distances, it is possible to view the radiographs at distances as short as 25 to 30 inches with but negligible distortion of the stereoscopic images. The best tube-shifts for various focus-film and eye-image distances are given in the table below. A $2\frac{9}{16}$-inch interpupillary distance is assumed, for this is reported generally in the medical literature to be average. The center of interest in the part radiographed is hypothetically located 4 inches from the plane of the film. The viewing distances may be 25, 28, or 30 inches.

Stereoscopic Tube Shifts for Common Focus-Film Distances at Various Eye-Image Distances

FOCUS-FILM DISTANCES	FOR EYE-IMAGE DISTANCE OF		
	25 inches Use Tube Shift of:	*28 inches* Use Tube Shift of:	*30 inches* Use Tube Shift of:
25 in.	$2\frac{9}{16}$ in.	$2\frac{1}{4}$ in.	$2\frac{1}{16}$ in.
30 in.	$3\frac{3}{16}$ in.	$2\frac{3}{4}$ in.	$2\frac{9}{16}$ in.
36 in.	$3\frac{7}{8}$ in.	$3\frac{7}{16}$ in.	$3\frac{1}{8}$ in.
42 in.	$4\frac{5}{8}$ in.	$4\frac{1}{16}$ in.	$3\frac{3}{4}$ in.
48 in.	$5\frac{3}{8}$ in.	$4\frac{11}{16}$ in.	$4\frac{5}{16}$ in.
60 in.	$6\frac{13}{16}$ in.	6 in.	$5\frac{1}{2}$ in.
72 in.	$8\frac{5}{16}$ in.	$7\frac{1}{4}$ in.	$6\frac{11}{16}$ in.
84 in.	$9\frac{3}{4}$ in.	$8\frac{1}{2}$ in.	$7\frac{7}{8}$ in.
96 in.	$11\frac{3}{16}$ in.	$9\frac{13}{16}$ in.	$9\frac{1}{16}$ in.



Radiograph of a shoulder.

Safety Measures

• An important consideration in radiologic practice is the provision and exercise of adequate safeguards for the protection of personnel and patients against the hazards of x-radiation and electric shock. The principal features of the necessary protective precautions are discussed in the following text but, in addition, more detailed literature on the subject should be studied carefully. It is suggested that copies of NBS Handbook 41, *Medical X-ray Protection up to Two Million Volts,** and *Safety Code for the Industrial Use of X-rays,*† and current safety recommendations of the International Congress of Radiology published in the radiologic journals from time to time, be preserved for reference.

X-ray Protection Any of the body tissues may be injured by overexposure to x-rays—the skin, blood, and some internal organs being particularly sensitive. This is a matter of vital concern to the radiographer — both for his personal safety and that of the patient. The radiographer is continually exposed to small amounts of secondary radiation, but he must avoid exposure to the more dangerous primary x-rays.

Unless exposure to x-rays or radium is kept at a minimum, the cumulative effect can be deleterious as indicated by measurable changes in the blood, alterations of glandular tissue, local loss of hair, or damage to the skin. *The radiographer must be adequately protected at all times against the hazards of radiation.*

In the usual x-ray examination, the radiation received by the patient is but a very small fraction of the amount that would produce bodily harm. Every patient, however, should be asked if he has been recently exposed to x-radiation for therapeutic or radiographic purposes. If exposure has occurred, the area and possible duration of exposure should be learned before further x-ray examination is made. The radiologist should be consulted in such cases.

The modern x-ray tube is usually surrounded with adequate protective material except at the exit for the primary x-ray beam. The construction of the tube is such that at the portal, inherent filtration equivalent to 0.5 mm. of aluminum is provided. However, an additional 0.5 mm. of aluminum filtration should be inserted in the filter channel for additional protection and never removed. The total amount of 1 mm. of filtration has little radiographic effect, and it is insurance of the greatest value. It also permits a greater number of exposures than if no filter were present.

The principal source of exposure

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*Apply to Superintendent of Documents, Washington 25, D. C. Price 15 cents; stamps are not accepted.

†Apply to American Standards Association, 70 East 45th Street, New York 17, N. Y. Price $1.50.

for the radiographer, however, arises from radiation scattered by the patient and any objects in the path of the beam. Therefore, while an exposure is being made, he should always be protected by at least 1/8 inch of sheet lead, or its equivalent. This can best be accomplished with a well-constructed nonmobile and lead-lined control booth fitted with lead-glass windows that permit a full view of the operating portion of the radiographic room at all times.

Special ionization chambers are available for measuring x-ray exposures received by personnel in the vicinity of an x-ray generator. As a test, one or more Radia-Tized Dental X-ray Film packets may be worn over the breast or carried in pockets of the clothing, with the tube side of the packet away from the body, for a period of 15 consecutive days. These films should then be developed for 5 minutes in fresh Kodak Rapid X-ray Developer at 68°F., with agitation of the films at the end of each minute of development. After processing, if the density of the film is sufficient to obscure newsprint when placed in contact with it, the protective measures should be investigated to determine their adequacy.

While these test films are being carried, a portion of each film should be covered with a lead letter. The presence of a letter-image on the film indicates that it has received penetrating radiation.

The constitutional effects from irradiation of the body have been established in some measure and the blood picture has been found to be a very sensitive index. Radiographers should be given monthly blood tests **so that evidence of the necessity for additional safeguards will be noted** in time to prevent damage to the blood from x-ray exposure. For this reason also, they should be allowed 4 weeks' vacation each year, most of it during the summer, so that considerable time may be spent in the open. They should also be given annual physical examinations. If protective measures are inadequate or the radiographer is careless, the body dose soon will exceed normal tolerance with manifestation of perhaps grave constitutional effects. Whenever there is doubt about the x-ray protective features of a laboratory, the radiologist or the manufacturer of the apparatus installed or to be installed should be consulted.

Electric Shock Protection The voltage used to energize a radiographic tube is extremely dangerous. When *non*shockproof equipment is being used, the best way to avoid electric shock is always to keep at a liberal distance from all the high-voltage conductors. The body must never be permitted to form a part of the high-voltage circuit, either across the tube leads or terminals, or between a high-potential lead and a low-potential lead or grounded conductor. The use of focus-film distances of 30 inches or more serves to keep the tube terminals out of easy reach of the patient, while *shockproof* x-ray tube enclosures and leads are excellent protective features that are particularly desirable with metal radiographic tables or chairs. Radiographic tables, which are constructed of wood, offer the advantage of effectively insulating the patient and greatly minimizing the danger should accidental contact occur with a high-potential lead.

The employment in the radiographic room of exposed low-voltage or grounded conductors, such as electric conduits, metal-topped radiographic tables, or water pipes, should be restricted. The floor should be covered with a good insulator, such as wood, linoleum, rubber, or cork.

In the processing room, low-potential electric outlets and fixtures may present a hazard. Special care should be exercised to prevent the body from becoming part of an electric circuit, because voltages of 110 or less may prove fatal if the electric contacts are made on moist skin. As a safeguard, the exposed portions of electric devices, including switches, plug outlets, and lamp sockets, should either be composed of insulating materials or be grounded. No electric appliance should be touched with wet hands or while any other part of the body is in contact with a grounded conductor, such as a water connection, processing tanks or fluids, or a concrete floor. In reaching for any electric fixture, the "one-hand rule" should be followed by keeping the other hand away from all objects. These same precautions should also be followed in handling the controls of the x-ray apparatus.

Radiographers should be familiar with the methods of applying artificial respiration, so as to be able to aid an unconscious victim of electric shock in case it should be necessary.

General Precautions All rooms in the x-ray department should be well lighted and well ventilated. If natural ventilation does not remove the nitrous gases and ozone, forced circulation of the air should be provided. Ample space should be allowed for the equipment and working areas, because any crowding increases the electric hazard.

Persons working in quarters adjoining the radiographic room should be shielded by adequate protective material in the walls, floor, and ceiling, since ordinary wood and plaster walls offer no appreciable protection. Metallic lead is usually the most suitable substance; however, seams must be lapped and nail heads capped with lead. Barium plaster is not fully effective for x-ray protective purposes because it is not uniformly homogeneous and, therefore, does not provide the same degree of protection over the area covered.

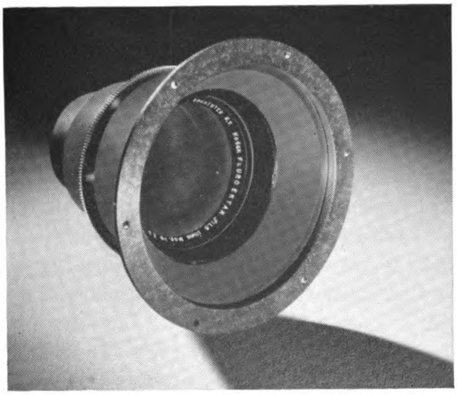
Photoradiography

• Mass radiography of the chest has assumed an important place in methods employed for the eradication of tuberculosis. Photoradiography is the term employed where chest surveys are made using miniature films. The method is a screening process which singles out possibly infected persons for further medical and x-ray investigation.

In spite of recent technical advances, photoradiography is an exacting procedure and requires knowledge and appreciation of many factors that are essential for optimum results. An analysis of some of these factors, with special reference to the characteristics and handling of Kodak products for photoradiography, is presented in this section. For a complete discussion of photoradiography, reference should be made to textbooks on the subject.

Lenses

Photoradiographic lenses must possess an extremely large aperture, critical sharpness and resolution at this aperture, and short focal length. Kodak Fluro Ektar Lenses, *f*/1.5 (one of which is reproduced as Figure 56, left) have been designed specifically for use in recording fluoroscopic images. They are constructed of seven lens elements (Figure 56, right), whose air surfaces are coated with magnesium fluoride to increase the light transmission and reduce flare. Recently developed optical glasses, including the new "heavy-element" Kodaglass, are utilized to increase their performance. These



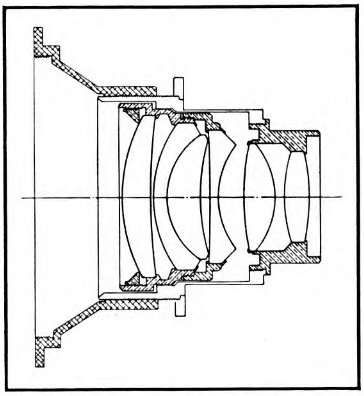


FIGURE 56—Kodak Fluro Ektar Lens, 111mm. *f*/1.5, and schematic drawing of the lens design.

Kodak Films for Photoradiography

KODAK PHOTOFLURE FILM—GREEN SENSITIVE

NUMBER	WIDTH	LENGTH
PF135	35mm.	36 exposures
PF135	35mm.	20 exposures
PF401	35mm.	50-ft. roll
PF402	35mm.	100-ft. roll
PF407	35mm.	250 exposures
PF414*	35mm.	100-ft. roll
PF470	70mm.	100-ft. roll

*Unperforated; wound on No. 10 spool.

KODAK PHOTOFLURE FILM—BLUE SENSITIVE

NUMBER	WIDTH	LENGTH
PF471	70mm.	100-ft. roll

KODAK SINGLE-COATED X-RAY FILM—GREEN SENSITIVE

SIZE	QUANTITY
$2\frac{11}{16}$x$6\frac{1}{2}$ in.	100 sheets

KODAK SINGLE-COATED X-RAY FILM—BLUE SENSITIVE

SIZE	QUANTITY
$2\frac{11}{16}$x $6\frac{1}{2}$ in.	100 sheets
4 x 5 in.	100 sheets
4 x10 in.	100 sheets

lenses are available with focal lengths of 145 millimeters, for use with 4x5-inch and 4x10-inch sheet film; 111 millimeters, for use with 70-millimeter film; and 50 millimeters, for use with 35-millimeter film.

Because these lenses are employed at maximum aperture (*f*/1.5), special care must be exercised to ensure critical focus. Experience has shown that photoradiographs in best focus are those in which the images of the lines produced by the stationary grid are superimposed over images of the entire lung fields. In examining photoradiographs for focus, a magnifier (×10) should always be utilized.

Apparatus

The apparatus for photoradiography consists of a high-speed camera mounted at one end of a lighttight hood; the other end contains a fluorescent screen upon which the image of the patient's chest appears upon x-ray exposure. Between the patient's chest and the screen, a stationary grid is mounted. The x-ray generator usually has a capacity of at least 200 Ma at 100 KvP and a timer that will provide exposures to at least a 1/10-second minimum. Some apparatus is equipped with an automatic phototimer which is mounted in the floor of the hood. For economy in operation, 150 Ma is advised when employing exposures in units of 1/10 second with a stationary anode x-ray tube.

Films

There are two basic types of Kodak single-emulsion films available for photoradiography — green sensitive and blue sensitive. As shown in the table above, they are supplied as Kodak Photoflure Film, in rolls 35 and 70 millimeters wide, and Kodak Single-Coated X-ray Film, in various sheet sizes. The green-sensitive films are used with green-fluorescing Du Pont-Patterson B, B2, and E2 Fluorescent Screens, while blue-sensitive films are employed in conjunction with the blue-fluorescing D or D2 Screens. When the fastest green and

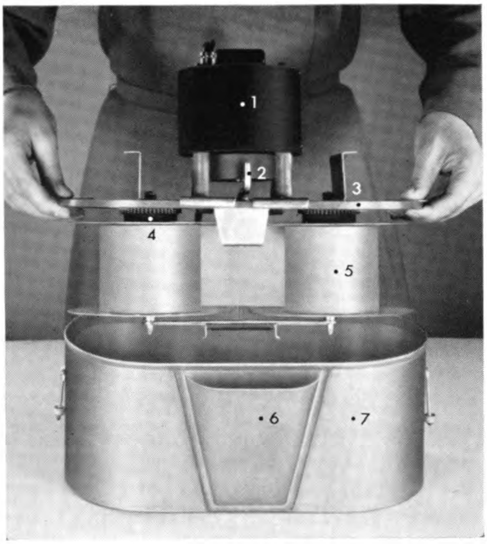


FIGURE 57—Fairchild motor-driven, rewind-type tank used in processing 70mm. Kodak Photoflure Film. LEGEND: (1) low-speed synchronous inductor motor; (2) hand crank; (3) cover; (4) winding mechanism; (5) roll of film on spool; (6) spout; (7) processing tank.

blue screens are used with the appropriate films, the speeds of the two systems are approximately equal at 100 Kv. However, below 100 Kv the blue combination is the faster, while above 100 Kv the green combination is the faster.

Both green- and blue-sensitive Kodak Photoflure Films are available in 70-millimeter width for use in the Fairchild Fluoro-Record Camera, F-212. However, only the green-sensitive film has been found useful in 35-millimeter width.

Kodak Single-Coated X-ray Film is manufactured in $2\frac{11}{16}$ x $6\frac{1}{2}$-inch sheets for use with both green- and blue-fluorescing screens. The blue-sensitive type is also available in 4x5- and 4x10-inch sizes.

Processing Accessories and Chemicals

Kodak Safelight Filters, Wratten Series 2, may be employed with either blue- or green-sensitive films, but Kodak Safelight Filters, Wratten Series 6B, may be utilized only with blue-sensitive films.

Two processing hangers are available: Kodak Adjustable Processing Hanger and Kodak X-ray Processing Hanger, No. 11.

The Kodak processing chemicals recommended for use in photoradiography are as follows: Kodak Liquid X-ray Developer and Replenisher, or Kodak Rapid X-ray Developer; Kodak Acetic Acid, 28%; Kodak Liquid X-ray Fixer and Replenisher; Kodak Photo-Flo Solution.

Solutions prepared from these chemicals may be stored in stoppered bottles preparatory to use. All used but unexhausted solutions should also be similarly stored.

Processing Procedures

Roll Films The majority of photoradiographic roll films are now being processed in motor-driven, rewind-type tanks (Figure 57). Although this method of processing is not difficult, it is more critical than that employed for conventional radiographs in deep tanks, and there are certain practices that should be rigidly followed in order to realize fully the capabilities of photoradiography. The remarks in this section apply primarily to the processing of 100-foot rolls of 70-millimeter Kodak Photoflure Film. The 50- and 100-foot rolls and the 250-exposure rolls of 35-millimeter Kodak Photoflure Film are processed in essentially the same way.

The leader and trailer should not be left attached to a roll of Kodak Photoflure Film while it is being processed. There are camera-activating perforations along the edges of the leader and trailer. If the film is rolled on spools in the tank so that the first and last few frames will be in contact with the leader and trailer, the perforations can be the source of oval areas of increased density on these frames. The alternative to removing the leader and trailer prior to processing is not to make exposures on the first and last three or four frames on the roll.

In transferring the film from the magazine of the camera to the spool of the tank, care must be exercised that the film be not injured by crimp marks or abrasions caused by inept handling. In addition, static will occasionally be created during this operation if the air humidity is low. This may be prevented if the magazine itself is placed temporarily on one of the spindles of the tank cover assembly, and the film threaded and started onto the processing spool. The entire assembly may then be immersed in water and the transfer of the film to the spool completed. The empty magazine reel is then removed and the other processing spool put in place.

It is important that the entire processing cycle be carried out at 68°F. Above 70°F., the emulsion may be softened to such an extent that the edges of the film may be damaged.

A shallow sink, measuring 30 inches in length, 20 inches in breadth, and 12 inches in depth, equipped with a standpipe, is very useful as a water jacket. The processing tank as well as the solution bottles can be placed in it for the regulation of the temperature. The sink should be supplied with hot and cold water, and either a mixing faucet or a thermostatic mixing valve, the latter being the more satisfactory. A rubber hose connected to the faucet or the valve outlet is important to facilitate filling or cleaning the processing tank and solution bottles, as well as for filling the water jacket.

Before describing the steps involved in the processing of 70-millimeter Kodak Photoflure Film, the following list is presented to show the *maximum* amount of film that may be processed in each of the required processing solutions:

> One gallon of developer solution made from either Kodak Liquid X-ray Developer and Replenisher or Kodak Rapid X-ray Developer may be used to develop 200 feet of film.
>
> One gallon of stop-bath solution (acid rinse) will stop development of about 100 feet of film.
>
> One gallon of fixer solution made from Kodak Liquid X-ray Fixer and Replenisher will fix 300 feet of film. The capacity will be less when short lengths of film are used.
>
> One gallon of solution made from Kodak Photo-Flo Solution should be used for 100 feet of film. Discard after each use.

To ensure optimum results, these recommendations should not be exceeded. When the requisite amount of film has been circulated through one of these solutions, the solution should be discarded.

The motor-driven, rewind-type tanks are designed with a spout so that only one tank need be used and the processing solutions poured in and out as necessary. However, experience has shown that it is much more convenient to use two tanks so that the motor-driven reel assembly can be removed from one solution and immersed in the next solution in a second tank with a minimum loss of time.

Prewetting Unless the film has been wound onto the processing-tank spool under water, it should be wet with water at 68°F. before being placed in the developer. This is done by running the film through the water-filled tank unit for 5 minutes.

Development The developing time is measured from the time of *immersion* in the developer to the time of immersion in the stop bath. This is most important. The developing time at 68°F. for the *first* 100 feet of Kodak Photoflure Film in one gallon of developer solution varies with the length of the roll being processed. These intervals, with solutions prepared from Kodak Liquid X-ray Developer and Replenisher or Kodak Rapid X-ray Developer, follow.

LENGTH OF FILM	DEVELOPMENT
6½ ft.	6 min.
25 ft.	8½ min.
50 ft.	9 min.
100 ft.	10 min.

The developing time should be increased by one minute for the *second* 100 feet of film processed in one gallon of developer solution.

Rinsing (Stop Bath) The film should be removed from the developer solution and immersed in the stop bath* as rapidly as possible. In order to stop development quickly over the entire length of film, it has been found desirable to wind the film *by hand* through two complete cycles in each direction. The procedure is more rapid than using the motor.

Fixation The fixing time of Kodak Photoflure Film in solution made from Kodak Liquid X-ray Fixer and Replenisher at 68°F. is as follows:

First 100 ft.	10 min.
Second 100 ft.	12½ min.
Third 100 ft.	15 min.

Washing To increase the flow of water through the motor-driven tank during the washing procedure, one end of the cover assembly should be propped up about ¼ inch. The hose nozzle is inserted into the bottom of the solution trap and the film should be washed for at least 25 minutes in rapidly running water.

Water-Spot Prevention Following washing, the flow of water should be stopped and the motor turned off. The lid of the tank with the film spools attached should be removed and about a pint of water poured from the tank. Next, ¼ ounce of Kodak Photo-Flo Solution should be added to the water. The lid and spools are then replaced and the motor is run for 5 minutes.

Drying All photoradiographic film requires care in drying. The procedure should be carried out in a room as free from dust as possible. After the film has been removed from the

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*To make Kodak Stop Bath SB-1A, add 16 ounces of Kodak Acetic Acid, 28%, to water to make one gallon of solution.

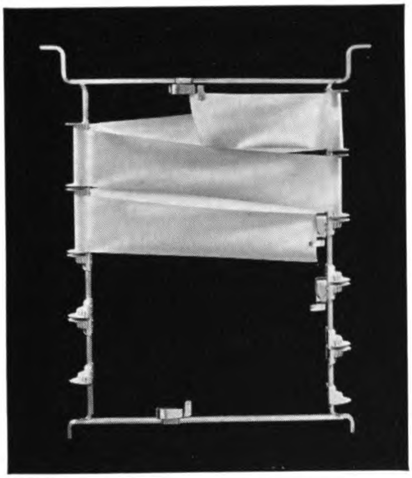


FIGURE 58—Strip of Kodak Photoflure Film (70mm.) attached to Kodak Adjustable Processing Hanger.

tank, all excess water should be eliminated by means of a chamois, cellulose sponge, or squeegee, and this should be done regardless of whether the film is to be dried in festoons or on a rack. If heat is used, the film should never be allowed to become bone dry since it will tend to become brittle. Allowing the film to remain for several hours in normal room atmosphere after drying will permit the equilibrium of moisture content of film and room.

When the film is dry, spots or finger prints may be removed with Kodak Film Cleaner.

Sheet Film and Short Lengths of Roll Film Standard tanks utilized to process 14x17-inch radiographs are employed for both sheets and short lengths of 35-millimeter and 70-millimeter photoradiographic films. Kodak Adjustable Processing Hanger is especially designed for the processing of any length of 35-millimeter and 70-millimeter film up to lengths of 11 feet. (See Figure 58.) Adjustable film guides accommodate strips of different widths, while sliding clips on the top and bottom bars hold the film smooth. Kodak X-ray Processing Hanger, No. 11, is of the channel type and holds five sheets of $2\frac{11}{16}$ x $6\frac{1}{2}$-inch film (Figure 59).

The processing procedure is the same as for conventional radiographs. *Green*-sensitive films are developed for 7 minutes at 68°F. in a solution made from Kodak Liquid X-ray Developer and Replenisher or Kodak Rapid X-ray Developer, while *blue*-sensitive films require 8 minutes. The difference is due to the fact that the films are coated with two entirely different emulsions. In all instances, an acid stop bath should be employed as a rinse between developing and fixing.

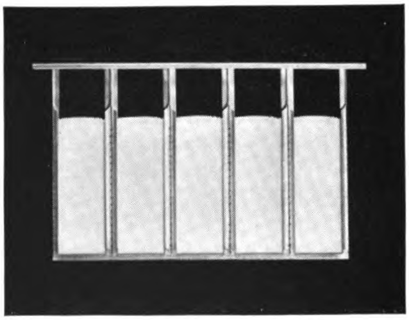


FIGURE 59—Sheets of Kodak Single-Coated X-ray Film ($2\frac{11}{16}$x$6\frac{1}{2}$ inches) in Kodak X-ray Processing Hanger, No. 11.

Appendix

Rapid Processing for Surgical Radiographs

• Occasionally, as an expedient in the course of a surgical operation, it is necessary to inspect at the earliest possible moment radiographs that are made as a part of the surgical procedure. In such situations, the normal processing time can be reduced by raising the temperature of the solutions to 75°F. For example, a film properly exposed for 3-minute development at 68°F. in Kodak Rapid X-ray Developer or Kodak Liquid X-ray Developer and Replenisher can be developed in 1¾ minutes if the solution temperature is 75°F.

Another method may be employed which makes use of a development period of 1 minute at 80°F. Cleared radiographs ready for viewing can be made available in a total processing time of 2 minutes. The developer solution is prepared from readily available standard packaged developer chemicals.

Method To prepare one gallon of developer, pour 43 ounces of Solution A, Kodak Liquid Developer and Replenisher into the developing compartment of a Kodak Dental Processing Tank, 8 x 10. (Solution B is discarded.) Sufficient water is then added to bring the total volume to one gallon. The temperature of the water should be such that, after mixing, the temperature of the whole solution will be 80°F. Obviously, if the temperature of Solution A is lower than that, the water to be added should be at a somewhat higher temperature, as indicated in the table below.

IF TEMPERATURE OF SOLUTION A IS:	TEMPERATURE OF WATER SHOULD BE:
60-65°F.	90°F.
65-75°F.	85°F.
80°F.	80°F.

A fresh fixing bath is next prepared in the fixer compartment; its temperature should also be 80°F. The master tank is then filled with water at a temperature of 80°F., and Kodak Photo-Flo Solution is added in the proportion of 1 ounce to a gallon of water. The presence of Photo-Flo Solution accelerates the removal of fixer chemicals from the film.

Procedure The exposed film is mounted in a hanger and immersed in the developer. The film is agitated rapidly and continuously throughout the development period of 1 minute. Continuous agitation is necessary to accelerate development and to avoid streaking. After development, the film is immediately immersed in the fixing bath (draining and rinsing are omitted) and agitated until the image is clear. It is next immersed in the wash water and agitated for 5 seconds. The radiograph is then ready

RC

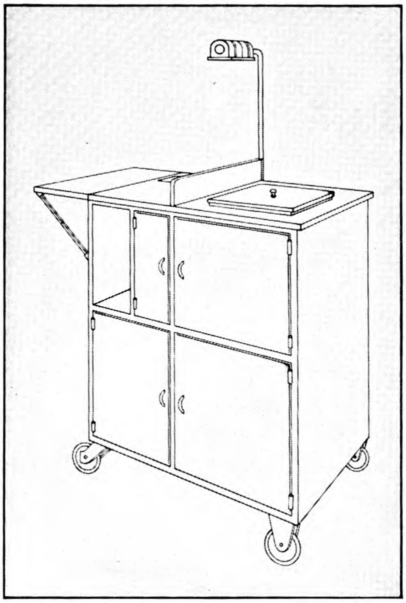


FIGURE 60

for viewing, after which it should be taken to the main processing room and thoroughly fixed, washed, and dried. Solutions should be made up fresh each time.

Mobile Processing Unit A convenient mobile unit for processing surgical radiographs is shown in Figure 60 and can be easily made. It can be thoroughly equipped and used in any dark closet near the operating room. Detail construction drawings are available from *Medical Technical Service,* Eastman Kodak Company, Rochester 4, N. Y.

Processing Films with Sea Water

While not recommended as a routine procedure, sea water can be utilized, in the same quantities as fresh water, to compound x-ray developers and fixing baths. The resulting solutions are turbid but will clear on standing. If time permits, it is best to allow the solutions to stand overnight, and to decant the clear fluid for use. If turbid solutions are utilized, however, it is essential that the surfaces of the films be carefully wiped off with a soft wet cloth or photographic cellulose sponge after washing and before drying, in order to remove any deposit.

Films washed in sea water should receive an additional final washing in *fresh* water for 5 minutes. This step is extremely important to prevent (1) the rapid fading of the image caused by residual salts in sea water in the presence of hypo; and (2) the absorption of moisture by hygroscopic salts. The chemicals of the processing solutions are removed from the film more rapidly with sea water than with fresh water; consequently, the washing time with sea water may be one half of the usual washing time. Washing in sea water may be carried out at lower temperatures than when fresh water is used. Temperatures of 50°F. or lower are feasible.

Removal of Fog or Stain from Radiographs

Although grid diaphragms, cones, and cut-out diaphragms are used extensively in routine radiography to reduce the amount of secondary radiation incident upon the film during exposure, under certain exposure conditions they are not quite effective and the radiographs may lack brilliance. This result can be counteracted to a certain extent by treating the film, after fixation, with Kodak R-8 Reducer.

Because of the long life and excellent keeping characteristics of this

KODAK R-8 REDUCER

	Avoirdupois	Metric
Water, at about 125°F. (52°C.)	20 oz.	625.0 cc.
Ferric Chloride, crystals	365 gr.	25.0 gm.
*Kodak Potassium Citrate	2½ oz.	75.0 gm.
Kodak Sodium Sulfite, desiccated	1 oz.	30.0 gm.
Kodak Citric Acid	290 gr.	20.0 gm.
Kodak Sodium Thiosulfate (Hypo)	6¾ oz.	200.0 gm.
Water to make	32 oz.	1.0 l.

Dissolve chemicals in the order given.

*Sodium citrate should not be used in place of potassium citrate because its use would slow up the rate of reduction considerably.

solution, it may be desirable to keep a tank of it on hand to treat radiographs which, because of faulty exposure, need fog clearing. If this is done, a tank of proper size should be placed adjacent to the one containing the fixer solution. After being fixed, the films are rinsed thoroughly and placed in the clearing solution at 65° to 70°F. for from 1 to 10 minutes — the time depending upon the amount of clearing desired. For the average film in which the presence of secondary radiation fog is not pronounced, 2 minutes' treatment is usually sufficient. Since the solution reduces the density of the radiographic image, it is best to control the degree of clearing by inspection rather than entirely by time. After clearing, the films must be washed thoroughly.

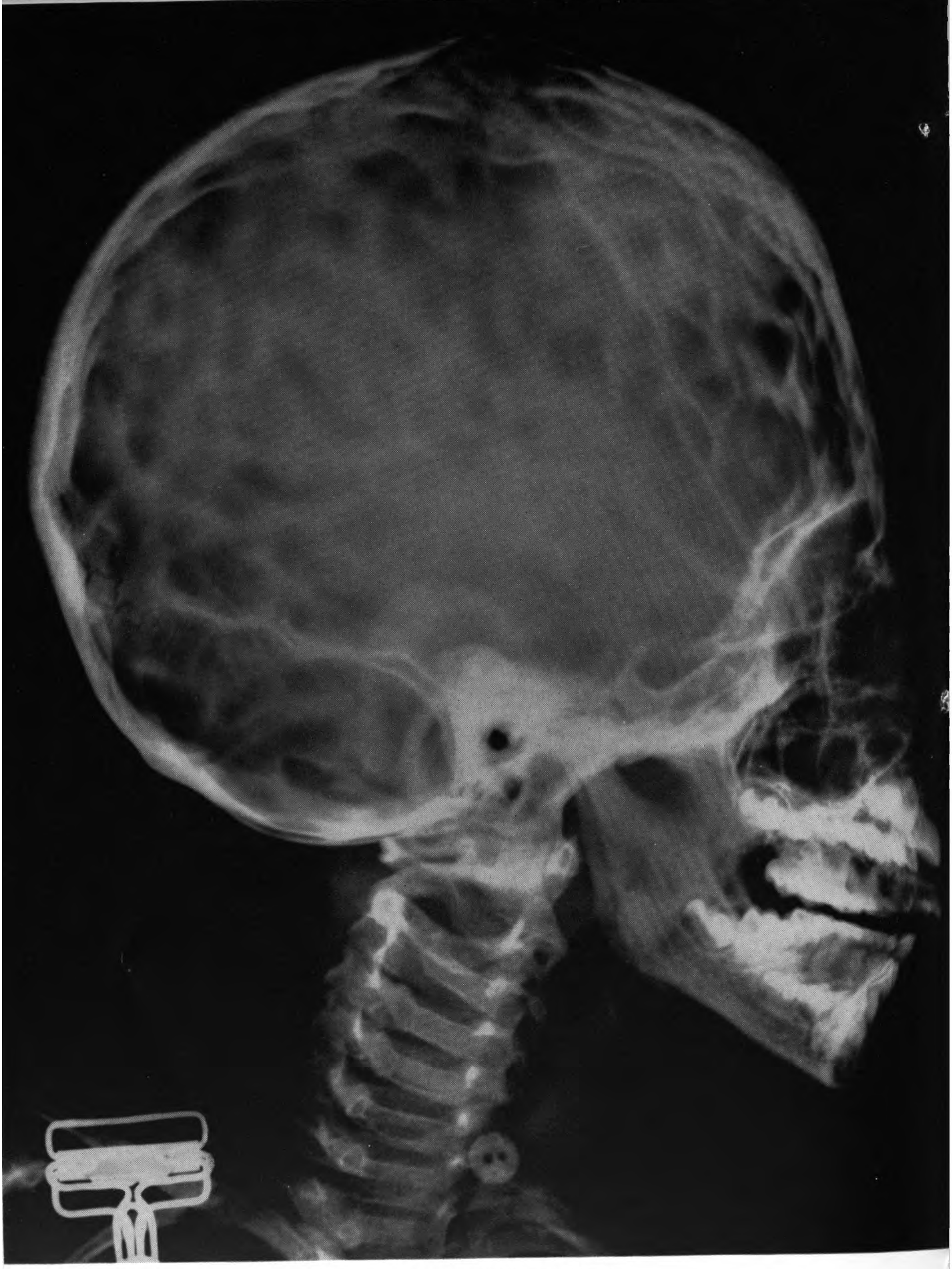
Radiographs that have been dried may be placed directly in this clearing solution; however, it is important that after being taken out they be washed as thoroughly as during original processing, to remove all the chemicals from the emulsion. The effects of fog due to overexposure or overdevelopment can thus be *partially* remedied.

If clearing is to be resorted to only occasionally, it may be found to be more convenient to use the packaged Kodak Reducer and Stain Remover instead of Kodak R-8 Reducer. This prepared powder needs only to be dissolved in water to be ready for use. However, with this solution the films must be washed entirely free of fixer solution before clearing. Because this solution is not stable, it must be made up just before using.

Adjustment of Processing Hangers

Bow springs of hangers that have been used for an extended period gradually lose their original tension, and, instead of producing tautness in the films, permit them to bulge. When several hangers exhibiting this deficiency are placed in the processing tank, areas of the films they hold may touch or even adhere to one another, preventing complete development and resulting in artifacts in the radiographs.

To correct the condition, the springs may be bent until the distance between opposite top and bottom clips, when not supporting a film, is slightly greater than the length of the film intended to be hung in the space. This can be readily ac-



Radiograph of Abnormal Skull.

complished by the following procedure: Place the hanger on the loading bench. Insert in the jaws of the lower clips a sheet of cardboard from a box of Kodak x-ray film of the same size as the hanger. Bend the bow springs upward until the lower tips of the clips attached to them are about 1/8 inch above the top edge of the cardboard. When this adjustment has been made, films that are placed in the hanger will again be held taut.

Cleaning Processing Equipment

Trays, tanks, and other processing equipment sometimes become discolored or coated with decomposition products of the photographic solution. While this may do no harm if a container is always used for the same kind of solution, it is much better to clean all containers each time they are emptied. The simplest method of cleaning a tray or tank is to wash it out several times with water and then wipe the surfaces with a clean cloth. This procedure is preferable to the constant use of strong cleaning solutions which should be resorted to only when washing is ineffective. Most cleaning solutions are either strong alkalies or acids and should be used with the same discretion given such chemicals when x-ray processing solutions are being prepared.

Trays and Tanks Stains from oxidized developer are usually of brown or yellow-brown color. Fresh stains can often be removed by washing with soap and water and wiping with a cloth. Severe stains require the use of a strong oxidizing solution such as Kodak Tray Cleaner TC-1 or TC-3. These cleaners will also remove most stains caused by deposits of silver or silver sulfide.

Developer tanks sometimes become coated with a scale consisting essentially of basic calcium sulfite which is difficult to remove by scrubbing. This scale is soluble in acids, but the ease of removal varies according to the conditions under which the scale was formed. As a first trial the tank should be filled with Kodak Stop Bath SB-1 and allowed to stand overnight. If this does not loosen the scale sufficiently, a 5 per cent solution of acetic acid should be tried or, as a last resort, a 2 to 5 per cent solution of hydrochloric acid. The latter should be used with extreme care, particularly on tanks made of stainless steel, because serious pitting may occur.

Large developer tanks of wood or stoneware often become coated with a layer of slime consisting of gelatin, organic matter, fungus and mold growths, and dust. Some of the molds or fungi can act on the sulfite of the developer and convert it to sodium sulfide, which is a strong fogging agent. Trouble from this source can be avoided by sterilizing the tank at regular intervals, especially during warm weather. The tank should be scrubbed thoroughly with a wire brush, then filled with a solution of sodium hypochlorite and allowed to stand overnight. It should then be emptied and given another thorough scrubbing and five or six washings before being used again.

Bleaching solutions that are sold for laundry use generally consist of sodium hypochlorite. If preferred, a solution can be prepared by adding sodium carbonate solution to a solution of calcium hypochlorite (bleaching powder) until no more precipatate is formed.

Film Hangers and Clips Metal film hangers and clips tend to accumulate a plating of silver when immersed in a fixing bath which contains dissolved silver salts. Such deposits are often of a spongy nature and may be mixed with gelatin and other substances. These deposits absorb chemicals from the processing solutions which are not removed by ordinary washing and when the hangers are reimmersed in the developer, some of these chemicals may leach out and cause fog on the film.

There are four methods of removing such deposits, and the choice of method will depend on the severity of the conditions. The acetic acid treatment is the simplest; boiling with trisodium phosphate, however, will be more effective in the majority of cases. Tray cleaner should be used with caution on metal equipment.

Acetic Acid Treatment: Soak the hangers or clips for an hour in a tray filled with 10 per cent acetic acid solution (1 part glacial acetic acid to 9 parts of water or 1 part 28 per cent acetic acid to 2 parts of water). The acid tends to loosen the deposit. Then wash with clear water and scrub the deposit with a stiff brush. Most deposits can be loosened and removed by this treatment.

Trisodium Phosphate Treatment: Boil the equipment for several minutes in a 10 per cent solution of trisodium phosphate; then wash it with water and scrub thoroughly with a stiff brush. This method is especially useful for cleaning deposits of spongy silver mixed with gelatin. This method should not be used for aluminum ware.

Acid Bichromate Treatment: If the silver deposit clings tenaciously to the metal hangers, it may be necessary to dissolve it with Kodak Tray Cleaner TC-1, diluted 1 part TC-1 to 2 parts of water.

The length of time the hangers or clips should remain in this solution depends on the quantity of silver to be removed. An immersion of 10 minutes is usually sufficient. When the articles are removed, rinse thoroughly and brush off any reddish-colored scale. It is advisable to use a glass or hard-rubber tray since an enamelled tray will be etched slowly by the cleaning solution. This solution should not be used on chromium-plated metal because it tends to destroy the copper undercoating.

Sandblasting: Heavy deposits of silver are best removed by having the equipment sandblasted.

Care of the Hands

Some years ago, cases of skin irritation resulting from the use of processing chemicals were frequently reported. It was found that the trouble was caused, in most instances, not by the developing agent employed but by certain impurities in the processing chemicals which, at that time, could not be removed. Improved manufacturing methods have since so eliminated these impurities that there are now very few complaints from such causes.

Occasionally, a case of skin irritation occurs because of the reaction of the individual to developers. Too much blame should not be placed upon processing chemicals because these appear to be included among a large variety of substances to which some individuals are hypersensitive. A few precautionary measures should always be observed by anyone who has allergic tendencies.

The simplest preventives are the wearing of rubber gloves; keeping hands out of solutions; rinsing the hands in a dilute acid bath immediately after using a developer solution. A 1½ per cent acetic acid solution, kept in a bottle nearby, makes a satisfactory hand rinse. After the hands have been bathed in the weak acid solution, they should be rinsed several times with plain warm water, after which soap and water may be used if desired. Soap should not be used immediately after the hands are removed from the developer, for it has a tendency to precipitate the insoluble base of the developing agent, which then remains in the pores of the skin. When the acid-solution and warm-water rinses are employed, the chemicals are not precipitated and trouble is avoided.

Even those not subject to this irritation should never allow developer solution to dry on the hands, because the crystallization of the chemicals may cause cracking of the skin, permitting access of chemicals to the deeper, sensitive layers of flesh.

The use of cotton gloves under rubber gloves will absorb perspiration and tend to keep the hands dry. Care should be taken not to contaminate the interior of rubber gloves with processing solutions, and it is advisable to keep two or three extra pairs of rubber gloves, changing them daily. The used gloves should be turned inside out and given the permanganate-sodium bisulfite treatment described below to remove any traces of developer. By following these precautions, it is possible for sensitive persons to work continuously in the processing room, with relative impunity.

Skin irritation may also be caused by the use of strong alkalies, acids, or oxidizing agents in removing developer stains from the hands. The best method for removing such stains is to apply a weak solution of potassium permanganate followed by a rinse in a sodium bisulfite solution. Two solutions (A and B) are prepared and placed in separate bottles. Solution A consists of ¼ ounce of potassium permanganate dissolved in 32 ounces of water. Solution B consists of 16 ounces of sodium bisulfite dissolved in 32 ounces of water. To remove developer stains, the hands should be bathed with a small amount of Solution A, and then rinsed with Solution B. The stains will disappear. The hands should next be washed in clear. warm water, dried well, and coated lightly with a lanolin cream. The cream must be removed, however, before screens or x-ray film are handled, since oily finger-marks would be reproduced as artifacts on the radiographs.

Removal of Stains from White Fabrics

White cotton uniforms often become soiled from developer and fixer stains that are not removed by ordinary laundering. Fresh unused fixer solution will not stain clothing but, as films are fixed, silver salts accumulate in the solution and may produce spots on clothing visible only after laundering.

If the garment is known to have been spotted with *used* fixer but is still unstained, it should be rinsed in fresh unused fixer solution and then rinsed well in water before laundering. If, however, a few spots are visible on the garment, tincture of iodine should be applied to them and allowed to remain about 5 minutes. The spots will turn inky black. Next, fresh liquid fixer should be applied to remove the color, and the garment should then be rinsed in cold water before laundering.

If the garment is badly spotted, it should be immersed in a solution made by dissolving ¼ ounce iodine crystals and ¼ pound potassium iodide in 1 gallon of water. (To avoid staining the hands, rubber gloves should be worn.) The garment should remain in the solution for 10 to 15 minutes and be stirred occasionally. Next, it should be rinsed in water, then in fresh unused fixer solution for 15 minutes or until completely bleached, and again rinsed before laundering.

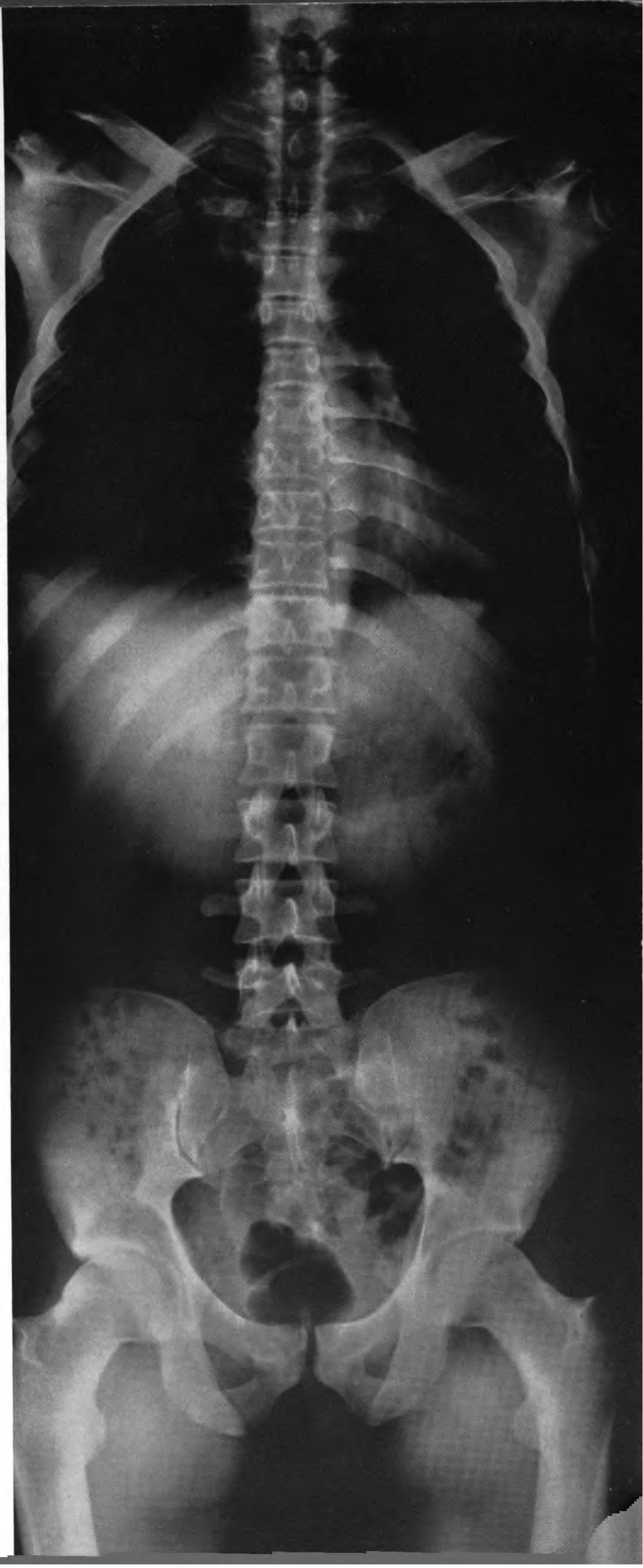
These methods should be very cautiously employed on any colored garment since an agent that will attack the stain may also affect the color. However, the possible number of stains can be materially reduced by wearing a Kodak Darkroom Apron.

Copying Radiographs

Quite often it is desired to make copies of radiographs, for reference to colleagues or for publication; projection slides may be wanted for lecture purposes; or transparencies may be needed for display. There are also many occasions when it is desirable to supplement the radiographic data with full-color or black-and-white photographic representations of conditions. Detailed information about efficient procedures that can be inexpensively employed in copying radiographs and in general medical photography will be supplied without charge, upon request to the *Medical Division,* Eastman Kodak Company, Rochester 4, N. Y.

Marking Radiographs

The radiologist often has occasion to indicate an area of interest in a radiograph for demonstration purposes to other physicians. Or, he may wish to record data concerning certain aspects of the image on the film. A Kodak All-Surface Pencil is excellent for these purposes. It is an ideal skin-marking pencil and may also be used to inscribe data on the filing envelope. Because it may be applied to all types of surfaces, this pencil is of value in every laboratory.



Radiograph of the
entire spine.

C

Kodak